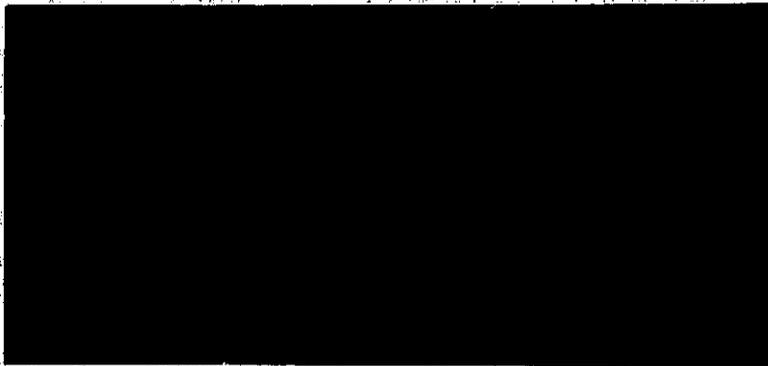


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E7.4-10229

CR-136492



(E74-10229) KANSAS ENVIRONMENTAL AND
RESOURCE STUDY: A GREAT PLAINS MODEL
Progress Report, Oct. - Nov. 1973
(Kansas Univ. Center for Research, Inc.)
62 p HC \$5.25

N74-15034

Unclas

CSCI 08F G3/13 00229



THE UNIVERSITY OF KANSAS CENTER FOR RESEARCH, INC.

2385 Irving Hill Rd. - Campus West - Lawrence, Kansas 66044

I. Summary of research objectives

Objectives of the investigation are: (1) to evaluate the effect of water stress, disease, and leaf area on the reflectance characteristics of wheat, (2) to evaluate disease losses in terms of yield and water use, and (3) to predict disease severity and economic loss.

II. Statement of problems

1. Delays in obtaining retrospective orders and the subsequent computer printouts from CCTs at University of Kansas adversely affect the completion of the final analysis by termination date (January 5, 1974).

III. Accomplishments during reporting period

1. Processed CCT and printed out grey scale maps.
2. Prepared manuscripts for publication.

IV. Planned accomplishments during next reporting period

1. Complete the final analysis of data.

V. Efforts to achieve reliability

1. Attempting to determine registration by repetition with different personnel.

VI. Significant results

Ground truth measurements indicate that reflectance ratios of the 545 and 655 nm wavebands provide an index of plant development and possibly physiological stress. Preliminary analysis of the corresponding ERTS channels (MSS 4 and 5) substantiate the ground truth interpretation.

IV. Discussion of planned accomplishments or work during next reporting period:

Two technical reports are in preparation and work will continue on these reports, which deal with (1) the study of alfalfa in Finney County and (2) the collection of land use statistics for the state of Kansas. In addition, preparation of the final report is continuing. The map of center pivot irrigation in Finney County is being updated for 1973.

V. Discussion of efforts to achieve reliability:

In our human interpretations, we employ a team approach. One interpreter analyzes the image. Then a second interpreter checks the work. Results are then checked against surface observations, available aerial photography and published data to determine the magnitude and causes of errors.

VI. Discussion of significant results and relationship to practical applications or operational problems:

Agricultural consultants have expressed substantial interest in our work on center pivot irrigation and have inquired as to how they may use ERTS-1 imagery to aid those in the irrigation field.

Results of the land use mapping experiment indicate that ERTS imagery has major potential in regionalization. The ways in which land is utilized within these regions may then be studied more effectively than if no adequate regionalization is available.

VII. Discussion and estimates of the cost benefits of any significant results:

Cost benefit analysis are not yet complete and will be included in the final report.

VIII. List of published articles, papers, pre-prints, in-house reports, abstracts of talks that were released during the reporting period after receiving notice of compliance with the provisions of Article IX of the contract:

None

ESTIMATE OF WINTER WHEAT YIELD FROM ERTS-1

Stanley A. Morain and Donald L. Williams
Department of Geography and Space Technology Center
University of Kansas, Lawrence

ABSTRACT

A model for estimating wheat yield per acre has been applied to acreage estimates derived from ERTS-1 imagery to project the 1973 wheat yields for a ten county area in southwest Kansas. The results (41.04 million bushels) are within 3 per cent of the preharvest estimates for the same area prepared by the USDA Statistical Reporting Service (39.91 million bushels). The projection from ERTS data is based on a visual enumeration of all detectable wheat fields in the study area and was completed while the harvest was in progress. Visual identification of winter wheat is readily achieved by using a temporal sequence of images (band 5 for Sept.-Oct.; band 5 for Dec.-Jan.; and band 5 & 7 for March-April). Identification can be improved by stratifying the project area into subregions having more or less homogeneous agricultural practices and crop mixes. By doing this, small changes in the spectral appearance of wheat related to soil type, irrigation, etc. can be accounted for. The interpretation rules developed by visual analysis can be automated for rapid computer surveys.

INTRODUCTION

Recent events in international politics have had great impact on the economy of U. S. agriculture. The "new" agricultural economics has focused attention on the need for rapid and timely estimates of crop acreage, yield, and general crop condition. Increasing world demand for U. S. agricultural products, coupled with increasing domestic demand, requires the development of means for assessing the status of major crops over large geographic areas at several points in the growing season. Even though present crop reporting methods are reliable for U. S. agriculture, a major shortcoming for efficient planning is the time lag between collection and dissemination of statistics. Techniques that can reduce the time lag in normal crop reporting procedures will undoubtedly have an impact on American agriculture. Similarly, any technique that will improve timeliness and accuracy of information on foreign agricultural production will benefit American agricultural policy makers. In this paper we describe our methods and results for estimating the winter wheat acreage and yield for a ten county area in southwest Kansas.

KANSAS ENVIRONMENTAL AND
RESOURCE STUDY: A GREAT PLAINS
MODEL

DECEMBER 1973

Type I Progress Report for the Period
October and November 1973

Prepared for:

National Aeronautics and Space Administration
Goddard Spaceflight Center
Greenbelt, Maryland 20771

Contract No. NAS 5-21822



THE UNIVERSITY OF KANSAS CENTER FOR RESEARCH, INC.

2385 Irving Hill Rd.—West Campus Lawrence, Kansas 66044



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KANSAS ENVIRONMENTAL AND RESOURCE STUDY:
A GREAT PLAINS MODEL

Use of Feature Extraction Techniques for the Texture
and Context Information in ERTS Imagery

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University of Kansas Center for Research, Inc.
Remote Sensing Laboratory
c/o Space Technology Center
Nichols Hall
2291 Irving Hill Dr.-Campus West
Lawrence, Kansas 66045

December 1973
Type I Progress Report for the Period October and November 1973
Report No. 2261-8

Prepared for:
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GODDARD SPACEFLIGHT CENTER
GREENBELT, MARYLAND 20771

Contract No. NAS 5-21822, Task 1

BIMONTHLY ERTS-A USER INVESTIGATION REPORT

Type I Progress Report
for the period ending: November 30, 1973

Title of Investigation: Use of Feature Extraction Techniques for Texture Context
Information in ERTS imagery

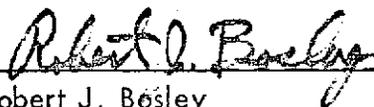
ERTS-A Proposal Number: 60-1

Task Number: 1

Co-Investigators: R. M. Haralick and G. L. Kelly

NASA-GSFC PI ID Number: UN 094

Report Prepared by:



Robert J. Bosley
Research Assistant

Report Approved by:



R. M. Haralick
Co-Principal Investigator

I. RESEARCH OBJECTIVES

The objective of this investigation is to study the spectral-textural features of ERTS imagery over Kansas as the basis for the discrimination between various land use categories.

II. PROBLEMS

None

III. WORK PERFORMED DURING THIS REPORT PERIOD

During this report period we have added an entropy measure to the six spectral-textural features and continued our study of these features on multi-image classification. The spectral-textural feature extraction programs were modified to provide optional subimage overlapping, variable distances between neighboring grey tone N-tuples, and horizontal processing of ERTS tapes in rows of subimages instead of vertical strips.

IV. PLANNED WORK FOR THE NEXT PERIOD

During the next reporting period we will analyze in detail the affect on classification of the entropy measure as a feature, plus the addition of second entropy order components to the grey tone N-tuples.

V. RELIABILITY EFFORTS

None

VI. SIGNIFICANT RESULTS

Improvement in the land use classification accuracy of ERTS MSS multi-images over Kansas can be made using two distances between neighboring grey tone N-tuples instead of one distance. Much more information is contained texturally than spectrally on the Kansas image and a slight improvement in classification accuracy is possible with the addition of the entropy measure as a new entropy feature.

VII. COST BENEFITS OF SIGNIFICANT RESULTS

None

VIII. PUBLISHED PAPERS, ARTICLES, REPORTS

None

IX. RECOMMENDATIONS REGARDING MAXIMUM UTILIZATION OF ERTS SYSTEM

None

X. CHANGES IN STANDING ORDER FORMS

None

XI. ERTS IMAGE DESCRIPTOR FORMS

None

XII. DATA REQUEST FORMS SUBMITTED

None

XIII. FUNDING

Funding is adequate

XIV. CHANGE IN PERSONNEL

None

KANSAS ENVIRONMENTAL AND RESOURCE STUDY:
A GREAT PLAINS MODEL

Interpretation and Automatic Image Enhancement Facility

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University of Kansas Center for Research, Inc.
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Lawrence, Kansas 66045

December 1973
Type I Progress Report for the Period October and November 1973
Report No. 2262-8

Prepared for:
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GODDARD SPACEFLIGHT CENTER
GREENBELT, MARYLAND 20771

Contract No. NAS 5-21822, Task 2

BIMONTHLY ERTS-A USER INVESTIGATION REPORT

Type 1 Progress Report
for the period ending: November 30, 1973

NASA Contract NAS 5-21822

Title of Investigation: Interpretation and Automatic Image Enhancement Facility

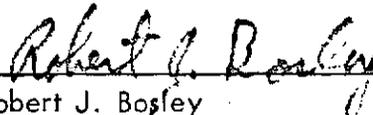
ERTS-A Proposal No : 60-2

Task Number: 2

Co-Investigators: R. M. Haralick and G. L. Kelly

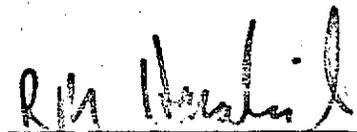
NASA-GSFC PI ID Number: UN 317

Report Prepared by



Robert J. Bosley
Research Assistant

Report Approved by:



R. M. Haralick
Co-Principal Investigator

I. RESEARCH OBJECTIVES

The main objective for the ERTS data processing facility is to provide the opportunity to use the analog and digital processing available at the University of Kansas for all ERTS investigators. The work under this task consists of: 1) developing user oriented digital software package for processing digital MSS data and 2) developing analog/digital package for processing transparencies for ERTS imagery on the IDECS/PDP-15 facility

II. PROBLEMS

None

III. WORK PERFORMED DURING THIS REPORT PERIOD

During this report period, we have continued to provide data processing support for ERTS investigators in Kansas. An extensive revision of the retrieval programs was made to provide better and more efficient data processing for ERTS tapes for Kansas investigators. Development continued on user oriented software packages for reading and displaying digital ERTS imagery for the IDECS color monitor. Work on a program to read ERTS tapes using the PDP-15/IBM-7094 facility was completed.

IV. PLANNED WORK FOR NEXT REPORT PERIOD

The participants of this module will continue to provide data processing support for ERTS Investigators in Kansas and also continue to develop user oriented software packages for digital/analog processing of ERTS imagery data.

V. RELIABILITY EFFORTS

None

VI. SIGNIFICANT RESULTS

None

VII. COST BENEFITS OF SIGNIFICANT RESULTS

None

VIII. PUBLISHED PAPERS, ARTICLES, REPORTS

None

IX. RECOMMENDATIONS REGARDING MAXIMUM UTILIZATION OF ERTS SYSTEM

None

X. CHANGES IN STANDING ORDER FORMS

None

XI. ERTS IMAGE DESCRIPTOR FORMS

None

XII. DATA REQUEST FORMS SUBMITTED

None

XIII. FUNDING

Funding is adequate

XIV. CHANGE IN PERSONNEL

None

KANSAS ENVIRONMENTAL AND RESOURCE STUDY:
A GREAT PLAINS MODEL

Wheat: Its Water Use, Production and Disease
Detection and Prediction

E. T. Kanemasu, Principal Investigator
Evapotranspiration Laboratory
Waters Hall
Kansas State University
Manhattan, Kansas 66502

December 1973
Type I Progress Report for the Period October and November 1973
Report No. 2263-8

Prepared for:
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GODDARD SPACEFLIGHT CENTER
GREENBELT, MARYLAND 20771

Contract No. NAS 5-21822, Task 3

BIMONTHLY ERTS-A USER INVESTIGATION
REPORT

TYPE I PROGRESS REPORT
for the period ending: November 30, 1973

NASA CONTRACT NAS5-21822

Title of Investigation: Wheat: It's Water Use, Production and Disease
Detection and Prediction

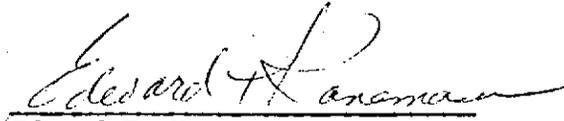
ERTS-A Proposal Number: 060-3

Task Number: 3

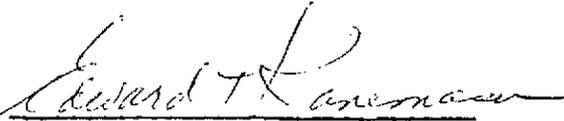
Principal Investigator: Edward T. Kanemasu

NASA-GSFC PI ID Number: UN 661

Report Prepared by:


Edward T. Kanemasu
Assistant Professor, Microclimatology

Report Approved by:


Edward T. Kanemasu
Principal Investigator

VII. Estimates of costs benefits

None

VIII. List of published articles

None

IX. Recommended changes in operation

None

X. Changes in standing order form

No longer receiving imagery

XI. Number of ERTS Image Descriptor Forms

None

XII. List of Data Request Forms

None

XIII. Discussion of Adequacy of Funds

None

XIV. Personnel Changes

None

KANSAS ENVIRONMENTAL AND RESOURCE STUDY:
A GREAT PLAINS MODEL

Extraction of Agricultural Statistics from
ERTS-A Data of Kansas

S. A. Morain, Principal Investigator
University of Kansas Center for Research, Inc.
Remote Sensing Laboratory
c/o Space Technology Center
Nichols Hall
2291 Irving Hill Dr. - Campus West
Lawrence, Kansas 66045

December 1973
Type I Progress Report for the Period October and November 1973
Report No. 2264-8

Prepared for:

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GODDARD SPACEFLIGHT CENTER
GREENBELT, MARYLAND 20771

Contract No. NAS 5-21822, Task 4

BIMONTHLY ERTS-1 USER INVESTIGATION REPORT

Type I Progress Report
for the period ending: 30 November 1973

NASA Contract NAS 5-21822

Title of Investigation: ERTS-1 Agricultural Statistics

ERTS-A Proposal Number: 060-4

Task Number: 4

Principal Investigator: Stanley A. Morain

NASA-GSFC PI ID Number: U664

Report Prepared by:

Donald L. Williams

Donald L. Williams
Research Assistant

Report Approved by:

Donald L. Williams

for Stanley A. Morain
Principal Investigator

I Summary of research objectives:

The long-term objective of this project is to develop remote sensors, particularly for use at orbital altitudes, as data sources for agricultural statistics. The immediate objectives are to identify wheat fields in Finney County, Kansas, and to make an assessment of acreage and crop vigor. A variety of methods for yield prediction is already employed by agricultural statisticians in government and industry, and the relationship between yield and weather is well established. Based on ERTS data and available weather records, an assessment of the feasibility of predicting yields will be made. This feasibility will be assessed in terms of accuracy and timeliness vis-a-vis present systems. If successful, the project will provide a model for estimating basic crop statistics and crop yields at regional, national and international scales. Under present strategies these data become available long after they are of practical use.

The objectives of this project are closely related to two other ERTS projects: a probabilistic crop type identification study by R. M. Haralick at the Center for Research, Inc., University of Kansas, and a study of wheat disease and pest recognition by E. T. Kanemasu at Kansas State University. Data and techniques developed in these two projects will materially assist in the solution of the agricultural statistics project.

II. Statement or explanation of problems impeding progress of investigation (i.e., explanation of any nonconformance with work schedule):

No impediments to the investigation have developed during this period and preparation of the final report is progressing.

III. Discussion of accomplishments or work performed during reporting period:

The analysis of winter wheat production results from ERTS has been prepared as a paper for the Third ERTS Symposium to be held at Goddard Space Flight Center December 1973. This paper, which summarizes results to date, is attached as Appendix A. Preliminary results of the semiautomatic interpretation algorithm are also included in the paper.

IX. Recommendations concerning practical changes in operations, additional investigative effort, correlation of effort and/or results as to maximum utilization of the ERTS system.

None

X. List by date of any changes in standing order forms:

None

XI. Number of ERTS Image Descriptor Forms (Attachment B) as required by Article VII of the contract:

These forms are being attached to the reports currently in preparation.

XII. List (by date) of any Data Request Forms (for retrospective data) submitted to NASA-GSFC/NDPF during the reporting period:

None.

XIII. Discussion of adequacy of funds to complete task.

All funds are presently adequate.

XIV. Description of any significant changes in operating personnel during the reporting period or anticipated during the next reporting period:

None

METHODOLOGY

Acreage, and yield per acre, represent the two measures required for a "crude" crop projection for any geographic area. We describe this as a crude projection because it does not consider differences in crop variety, protein content, crop lost during harvesting or other refinements on the amount of grain actually delivered to storage bins. Nevertheless, by using ERTS as the data base, projections can be announced several months in advance of current, equally crude, projections announced by the crop reporting service.

Wheat Acreage Estimates

A report on our technique for estimating winter wheat acreage in southwest Kansas was published in the Goddard Symposium on Significant Results using ERTS Imagery (Williams, et. al., 1973). In this document, a procedure for visually detecting and enumerating wheat fields on ERTS imagery is described.

Basically the technique requires the interpreter to:

- 1) delineate county boundaries on the imagery;
- 2) recognize and delineate agricultural subregions within each county on the basis of differences observed in the imagery (the boundaries of many of these subregions will cut across county boundaries;
- 3) compare the results of step 2 with soil and landform maps (for those counties where they exist) in order to better estimate the importance of the crop in each land-use region;
- 4) learn to distinguish the image tones of wheat in fields 80 acres (approx. 32 ha) or larger from those of other important crops in the subregion and convert these into interpretation rules applicable to that subregion, and;
- 5) visually locate and estimate the acreage of wheat fields in each subregion using the interpretation rules developed in step 4. From the subregion totals a composite acreage is obtained for the entire project area.

Accuracy and Advantages of ERTS Visual Analysis--By using the above procedure we have found through comparisons with ground truth and aircraft underflight data that 99 per cent of all the wheat fields and 99 per cent of the total acreage can be accurately estimated. Although the interpretation rules are created from grey tones of fields larger than 80 acres, the rules can be applied to all field sizes as small as 10 acres providing there is high tone contrast with their surroundings. An obvious advantage in the Winter Wheat Belt is that, once identified as wheat, the acreage of each field can be accurately estimated because field sizes, by the township and range system of survey, are characteristically 10, 40, 80, 120, 160 or 320 acres (4, 16, 32, 48, 64 or 128 ha respectively).

There are at least three other advantages of visual interpretation from ERTS. First, with experienced interpreters who are familiar with the cultivation of winter wheat, the time involved for a complete enumeration of each county is on the order of one hour per 250 square kilometers. While this is considerably longer than would be

required using a computer (assuming it could be trained to identify wheat) it is also much cheaper. Secondly, by visual analysis, we obtain a nearly complete enumeration of the crop and learn how its spectral properties vary geographically and temporally. Thirdly, because we identify and locate each field early in the crop cycle, the need for ground truth and aircraft data diminishes through time and allows us to concentrate those activities in areas where spectral anomalies (disease, stress) begin to appear.

The Need for Sequential ERTS Data -- Estimates of winter wheat acreage would not be possible without sequential ERTS data. The crop calendar for wheat is unique among those crops commonly grown in the Great Plains. It is planted in September or October depending upon weather conditions. By late November it is the only green crop in the agricultural scene and can be readily detected and enumerated on MSS band 5 (the chlorophyll absorption band). It is significant that these circumstances coincide with the most cloud-free season of the year over this region. With a high probability for at least one cloud and snow-free image, a complete enumeration of wheat planted is virtually a fait accompli. In addition, by virtue of slight tonal variations at this time of year, we feel that it will be possible, given more detailed observation, to categorize differences in planting time and general wheat condition.

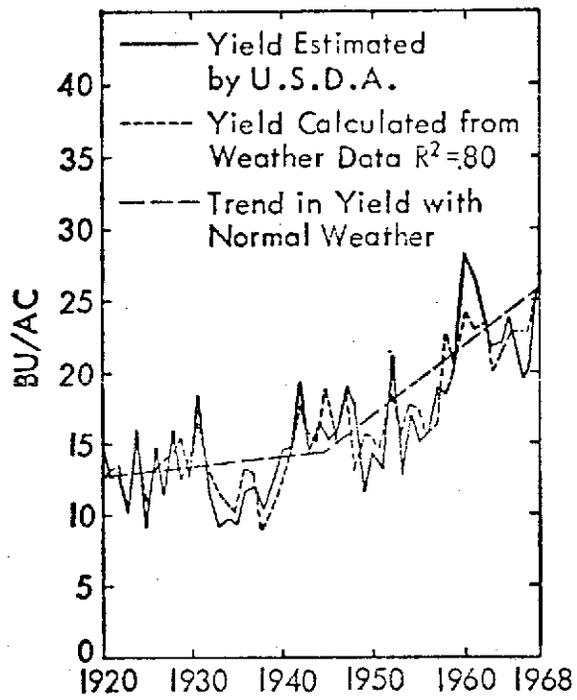
A second look at wheat is required during March or April in southwest Kansas. We used imagery from this time period to adjust the initial acreage estimate and to assess general wheat condition. This was necessary because a popular practice in western Kansas is to plant wheat as a winter forage and soil protection measure with no intention of later harvesting the crop. In spring the field is turned under to provide green manure and replanted to another crop. Such acreage must be subtracted from the initial estimate. A combination of the red and infrared bands is desired for these early spring observations.

A final ERTS observation is recommended during the harvest season. This is perhaps not as important at present as it could be in the future, after we learn to interpret and adjust estimates for crop loss due to disease, hail damage, etc. Individual fields can be turned under as late as June and still produce a cash crop. An estimate of wheat acreage actually harvested therefore is desirable. It is, of course, true that other crops, in addition to wheat, can be surveyed using the same set of above images. Alfalfa, for example, can be visually distinguished from wheat in May and early June on band 7. At this time of year alfalfa is growing vigorously (bright on band 7) while wheat is drying for harvest (medium tone on bands 5 and 7).

Yield Per Acre Estimate

The model we have used for estimating average yield per acre was proposed by Thompson (1969). It is based on departure from average weather conditions. According to his results, highest yields in Kansas are associated with above normal precipitation from August through March (normally a total of 325 mm.). Each additional 25 mm. at this time of year results in a gain of approximately 0.63 bushels per acre. High yields are also associated with above normal rainfall in April, normal rainfall in May and below normal rainfall in June. As a rule these months receive 88, 120 and 103 mm. of moisture respectively. Finally, for optimal yields in Kansas, below normal temperatures during April, May and June are best. With these data, it is possible to calculate an expected yield per acre. A comparison of actual and calculated yields is given in Figure 1.

FIGURE I
ACTUAL AND CALCULATED YIELDS
AND TREND OF WHEAT YIELD IN
KANSAS (FROM THOMPSON, 1969)



Weather data suitable for use in the model are published by the U. S. Weather Bureau in its monthly climatological survey of each state. These data are published for each station and the stations are grouped into districts. The southwestern Kansas district includes the ten counties surveyed in this report and mean weather conditions in that district were used in solving the equation developed by Thompson.

Semi-Automatic Interpretation

The interpretation rules developed for visual interpretation can be specified in a computer compatible form for rapid wheat acreage surveys. At present the technique is termed semi-automatic because both the pre- and post-processing time involve human activities. In broad outline the procedure requires the interpreter to:

- 1) specify the coordinates of subareas on the image which match county boundaries or other geographic localities. Care must be taken to specify the location of towns or other non-cropland sites in order to exclude these from later tabulations.
- 2) create a frequency histogram for the 128 "tones" on the data tape for each area specified in step 1.
- 3) divide the histogram into 15 levels (roughly equivalent to the 15 gray level steps found on each MSS image).
- 4) determine the total number of resolution cells contained within those gray levels that have been determined by visual analysis to closely correspond to wheat. Since each resolution cell is approximately equal in size to one acre (.4 ha), the number of cells is considered to be roughly equal to the wheat acreage.

An estimate from this procedure for an 840 sq. mile (2,184 sq. km) area in Finney and Gray Counties totaled 165,000 acres. The same area, by visual tabulation, contained 162,000 acres. Although the time required for the semi-automatic approach was about half (10 hrs. vs. 5 hrs.), the cost was almost four times (\$120 vs. \$30). At present we do not consider these differences to be meaningful because of the research environment under which they all were derived. Our two strongest views at this stage of development are that:

- 1) we see no way of ever eliminating the pre-processing human time required for crop surveys, simply because there are too many decisions and "bookkeeping" operations involved in a reliable inventory, and;
- 2) we may require a visual analysis in any case so that we can locate and monitor individual fields.

RESULTS

Table 1 gives our estimate of wheat acreage for the ten county survey area (approximately 8,071 sq. miles or 21,000 km) and compares it with estimates prepared by the Statistical Reporting Service (SRS) of USDA. The ERTS estimate was prepared in March whereas the data available from SRS represent their May and August estimates of "harvestable" acreage. Final figures from SRS will not be available until February 1974, but, assuming that their August estimate is more accurate than their May estimate, the final tally should not differ significantly from the original ERTS total. The March ERTS estimate is within 0.5 per cent of the SRS August estimate.

Table 1
Comparative Estimates of 1973 Wheat Acreage (and yield in bu/ac)
for Ten Counties in SW Kansas
as Compiled by USDA, SRS and by Analysis of ERTS Imagery

County	SRS		Ave. Yield	ERTS
	Acreage Est. May 1973	Aug. 1973		Acreage Est. March 1973
Finney	205,000	198,000	(37)	239,000
Grant	81,000	87,000	(34)	74,000
Gray	157,000	162,000	(36)	174,000
Haskell	104,000	109,000	(43)	110,000
Kearney	117,000	119,000	(31)	115,000
Meade	141,000	132,000	(36)	151,000
Morton	91,000	97,000	(24)	72,000
Seward	83,000	80,000	(36)	78,000
Stanton	135,000	132,000	(24)	108,000
Stevens	85,000	87,000	(31)	86,000
	<u>1,199,000</u>	<u>1,202,000</u>	(33.2 ave.)	<u>1,207,000</u> (34)

Also shown in Table 1, in parentheses, are the SRS projected average yields per acre, for August, for each of the ten counties. Our estimate for the entire area, as calculated by the Thompson model, is given in parentheses in the row of totals. These values have been combined into a matrix as shown in Table 2. The upper left cell represents the total crude yield that would be obtained using the traditional, time-tested techniques and an average of 33.2 bushels/ac. The lower right cell gives the expected wheat yield using ERTS imagery and the methodology reported in this paper. The ERTS estimate of total wheat bushels is 2.8 per cent higher than the SRS estimate. It predates the SRS estimate by about two months.

Table 2
Matrix of Total Estimated Yield
Comparing SRS and ERTS Data

		Average Yield/Acre	
		SRS (33.2 bu/ac) as of 8/73	ERTS (34 bu/ac) as of 6/73
Harvestable Acreage	SRS (1.207 x 10 ⁶) as of 3/73	39.906 x 10 ⁶ bu	40.848 x 10 ⁶ bu
	ERTS (1.202 x 10 ⁶) as of 8/73	41.193 x 10 ⁶ bu	41.038 x 10 ⁶ bu

DISCUSSION OF THE RESULTS

The above results include several points that need amplification. One could argue, first, that if the ERTS acreage estimate is based on a total enumeration of fields instead of a sample, as normally employed by SRS, and that, further, if SRS has a more sophisticated technique for calculating average yield per acre than that proposed by Thompson, the combination of these two values might give an even better estimated yield. This value is presented in the lower left cell of Table 2 and is approximately 3.1 per cent higher than the SRS tally. Final figures, when presented, may support this argument.

A second argument concerns the complex economics of irrigated wheat and wheat planted as winter forage. Irrigation by center pivot methods is increasing rapidly on the lighter textured soils of the southwest (Williams and Barker, 1972). In past years many irrigated fields have been planted to wheat as a winter cover crop and replanted in spring to feed grains. However, the recent high price of wheat, combined with the prospect for continued international wheat trading and low domestic reserves has stimulated growers to harvest wheat that would otherwise have been turned under. Yields on irrigated wheat fields in 1973 are estimated on the basis of past performance at 53 bushels/acre. We estimate from ERTS imagery that in 1973 174,000 acres of harvestable wheat were irrigated in the project area. Using these inputs we can revise the original yield estimate, as shown in Table 3, to a total of 44,344 million bushels, or 17 per cent higher than the August SRS estimate. Again, only the final figures, when released by SRS, will reveal whether this refinement is reasonable. No distinction is made between irrigated and dryland wheat in the SRS estimate presented but such distinction is made in the final February data. We believe that our ERTS derived estimate for harvestable irrigated wheat in 1973 is reasonable since SRS reported 202,000 acres of planted irrigated wheat in 1972 (personal communication).

Table 3
 Revised Yield Estimate
 from ERTS to Include Irrigated Acreage

Type	Acreage ($\times 10^3$)	Ave. Yield (Bu/Ac)	Total Yield ($\times 10^6$ Bu)
Irrigated	174	53	9.222
Dryland	1033	34	35.122
Totals	1207	-	44.344

REFERENCES

ERTS-1 Imagery:

<u>DATE</u>	<u>FRAME NUMBER</u>	<u>QUALITY</u>
8-16-72	1024-16511-5	Excellent
9-21-72	1060-16505-5	Good, partial cloud cover
9-21-72	1060-16512-5	Good, partial cloud cover
9-22-72	1061-16564-5	Good
9-22-72	1061-16570-5	Good
12-21-72	1151-16575-5	Good, partial snow cover
3-20-73	1240-16523-5	Good, partial snow cover
5-31-73	1312-16520-5	Excellent
7-24-73	1366-16512-5	Excellent

Thompson, Louis M. (1969), "Weather and Technology in the Production of Wheat in the United States," Journ. of Soil and Water Conservation 24:6 (Nov.-Dec.), pp. 219-224.

Williams, D. L. and Barker, B. (1972), "Center Pivot Irrigation in Finney County, Kansas: An ERTS-1 Interpretation Procedure." Lawrence, Ks: Center for Research, Inc. NASA-CR-131208, 14 p.

Williams, D. L., Morain, S. A., Barker, B. and Coiner, J. C. (1973), "Identification of Winter Wheat from ERTS-1 Imagery," in Symposium on Significant Results Obtained From the Earth Resources Technology Satellite-1, Vol. 1, edited by S. C. Freden, E. P. Mercanti, and M. A. Becker. Washington D. C: National Aeronautics and Space Administration, pp. 11-18.

KANSAS ENVIRONMENTAL AND RESOURCE STUDY:
A GREAT PLAINS MODEL

Monitoring Fresh Water Resources

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Moore Hall
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December 2973
Type I Progress Report for the Period October and November 1973
Report No. 2265-8

Prepared for:

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GODDARD SPACEFLIGHT CENTER
GREENBELT, MARYLAND 20771

Contract No. NAS-21822, Task 5

BIMONTHLY ERTS-A INVESTIGATION REPORT

Type I Progress Report
for the period ending: November 30, 1973

NASA Contract NAS 5-21822

Title of Investigation: Monitoring Fresh Water Resources

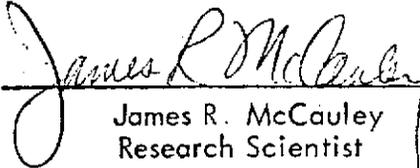
ERTS-A Proposal Number: 060-7

Task Number: 5

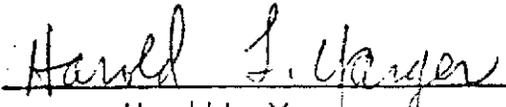
Principal Investigator: Harold L. Yarger

NASA-GSFC PI ID Number: ST045

Report Prepared by:


James R. McCauley
Research Scientist

Report Approved by:


Harold L. Yarger
Principal Investigator

I. Summary of research objective (s):

It is the objective of this study to determine the feasibility of monitoring fresh water bodies in Kansas using ERTS-1 imagery. This is to be accomplished by attempting to correlate spectral reflectance with water properties and analysis measured at the time of overflight on two reservoirs under intensive study (Tuttle Creek and Perry Reservoirs).

II. Statement or explanation of problems impeding progress of investigation (i.e., explanation of any nonconformance with work schedule).

None

III. Discussion of accomplishments or work performed during reporting period

Water samples have been collected for 16 of the 23 cloud free reservoir passes. Conditions such as ice cover, high wind and mechanical failure prevented sample collection for the remaining 7 cloud free passes. This report is based primarily on the analysis of computer compatible tapes (CCT's) from 11 reservoir passes with ground truth which includes sun angles above the horizon of 25° to 62° (Figure 1). Qualitative analysis of ERTS-1 9.5" positive transparencies appear in earlier presentations (Yarger, 1972 and 1973).

Sun Angle Effects

The multispectral scanner (MSS) in ERTS records light reflected from a scene illuminated by an admixture of sunlight and skylight (Figure 2). On relatively clear days the spectral shape of the illumination remains fairly constant throughout the year. However, the intensity, angle of incidence, and path length through the atmosphere depend on sun angle (angle above horizon). The reflectance levels from the concrete dam at Tuttle Creek Reservoir, a target with constant spectral reflectance, demonstrate a sun angle dependence in all MSS bands (Figure 3). As has been suggested by Vincent (1972), the sun angle dependence is suppressed by plotting band ratios instead of absolute levels (Figure 4). The three other possible ratios, not plotted in figure 4, also show a flat response to change in sun angle. Ratioing essentially removes the effect of unequal illuminating intensities caused by the continuously changing sun angle from one ERTS pass to the next. Since the ratio curves for the dam are flat, the angle of incidence and atmospheric scattering of reflected light are not important factors, at least for a concrete target.

Water reflectance levels do not exhibit as strong a dependence on sun angle, but there is a significant measurable effect (see Figure 5 for band 5 example). As for concrete, the absolute, reflectance levels for water decrease with lower sun angle. In addition, the correlation (or slope) between reflectance level and suspended solids, in the range 0-90 ppm, appears to depend on sun angle. On the other hand, the magnitudes of MSS5/MSS4 ratios are indistinguishable for the three different sun angle passes (Figure 6). The slopes (ratio vs. suspended solids) for the two low sun angle passes remain fairly flat. A dark object subtraction on each band before ratioing, as suggested by Vincent (1972), does not significantly change the slopes of the three passes. Dark object subtraction, which is the absolute level detected by ERTS minus level of darkest object in scene, should suppress atmospheric scattering effects present in the ratios. These results indicate that the slope dependence on sun angle is probably not due to atmospheric scattering. It is perhaps due to water column reflectance dependence on illuminator angle of incidence.

There were no obvious anomalous conditions during the low sun angle passes such as high wind or chemical concentration. Lower temperatures should not significantly effect water volume reflectance (Scherz, 1971). Reflectance levels from eight passes with sun angle $\geq 45^\circ$ exhibit much weaker dependence on sun angle, but ratioing nevertheless improves correlation with suspended load, particularly for bands 4 and 5. The 3 passes with sun angle $\geq 40^\circ$ exhibit lower correlation with suspended load, but the suspended load range 20 to 60 ppm is small compared to the range 0 to 900 ppm for all the data. More points at higher suspended load and low sun angle are needed to statistically confirm a band ratio-suspended solids correlation dependence on sun angle. For the remaining discussion it is assumed that, after ratioing, sun angle dependence is relatively unimportant.

CCT Correlations with Ground Truth

Digital levels for each water sample were extracted from the CCT by locating the sample station coordinates on a CCT generated gray level map, then averaging 9 pixels centered around the coordinate which corresponds to a 240 x 240 meter square area on the water surface.

Band 4 shows no correlation beyond ~ 50 ppm and is useful only for relatively clear water (Figure 7). This green band penetrates the water column more than the other bands (Figure 2), but as a consequence encounters a large amount of scattering

material which produces saturation or maximum scattering at levels ≥ 50 ppm. Band 5 is correlated with somewhat higher turbidities (≥ 80 ppm) but its response to suspended load is quite similar to band 4 (Figure 8). Band 5 ratioed with band 4 (Figure 9) improves suspended load correlation and is roughly linear in the range of 0 to 80 ppm with RMS residual of 12 ppm (Figure 10). All regression analysis in this report was done with horizontal axis as the dependent variable and vertical axis as the independent variable.

Band 6 and the ratio band 6/band 4 display good correlation with suspended load over the entire range of 0 to 900 ppm (Figure 11 and 12). A smoothly varying polynomial fit yields an RMS residual of 31 ppm. A similar fit (not shown) to the non-ratioed curve in figure 11 yields an RMS residual of 48 ppm., so that a significantly better fit was achieved by ratioing. As is the MSS5/MSS4 ratio, the MSS6/MSS4 is linearly related to suspended solids in the region ≤ 100 ppm. The response of band 7 (not shown) and band 7/band 4 (Figure 14) to suspended load is somewhat weaker than the other bands but is definitely correlated with accuracy level ~ 50 ppm.

Figure 15 is an example of a suspended solids contour map of Tuttle Creek Reservoir (August 14, 1972) which was produced using a correlation curve between band 5 and suspended solids. The curve (not shown) was derived from four high sun angle passes which yielded an RMS residual of 5 ppm.

Band ratio correlations with secchi depth (or maximum light penetration depth) are shown in figures 16, 17, and 18. The MSS5/MSS4 ratio is able to predict secchi depth (or water clarity) to within ± 20 cm. to at least a 1 meter depth, which is the limit of this investigation. The ratios MSS6/MSS4 and MSS7/MSS4 yield reliable results for the more turbid water conditions corresponding to secchi depth in the range 0 to 40 cm and 0 to 20 cm respectively.

A study of ratio curves for MSS6/MSS5, MSS7/MSS5, and MSS7/MSS6 (not shown) indicates that these ratios are not very useful for correlation with suspended load or secchi depth.

IV. Discussion of planned accomplishments or work during next reporting period:

It appears that gray levels obtained from electronic level slicing of 9.5" black and white ERTS images will yield quantitative correlation with suspended load similar to that achieved using CCT's and with nearly the same accuracy. This part of the investigation will receive attention during the next reporting period because of the greater practicality and cost - effectiveness of the images as opposed to the CCT's.

In addition, attention will be directed to the other water quality parameters that have been regularly determined in an effort to uncover any slight correlations.

Chlorophyll and algal nutrients will receive particular attention. Thus far MSS5/MSS4 ratios show no obvious correlation with chlorophyll concentrations up to 10 µg/liter.

V. Discussion of efforts to achieve reliability:

Examination of the reflectance from the vegetation free Tuttle Creek floodway on CCT's for 8 passes shows a strong dependence on sun angle (Figure 3). Band ratios appear to remove this sun angle dependence (Figure 4). Water reflectance also shows a significant dependence on sun angle as shown in Figure 5. MSS5/MSS4 ratios for the same set of data are plotted in Figure 6 and the three different sun angle passes are indistinguishable. This and other data indicate that MSS band ratios derived from CCT's can significantly reduce the sun angle dependence of water reflectance.

VI. Discussion of significant results and relationship to practical applications or operational problems:

Inorganic suspended load is the dominant influence on reservoir reflection levels. MSS band ratios derived from CCT's can be used for reliable prediction of suspended load up to 900 ppm during at least the high sun angle warmer months and perhaps the entire year (see discussion on sun angle). The ratio MSS5/MSS4 is useful in the range 0 to 80 ppm with accuracy on the order of 10 ppm. The ratios MSS6/MSS4 and MSS7/MSS4 are useful from 0 up to at least 900 ppm, which is the limit of this investigation, with accuracies of 30 ppm and 50 ppm respectively.

VII. Discussion and estimates of the cost benefits of any significant results:

None

VII. List of published articles, papers, pre-prints, in-house reports, abstracts of talks that were released during the reporting period after receiving notice of compliance with the provisions of Article IX of the contract:

"Quantitative Water Quality with ERTS-1" by Harold L. Yarger, James R. McCauley, Gerard W. James, Larry M. Magnuson and G. Richard Marzoff. Presented at the Third ERTS-1 Symposium December 10-13, 1973 in Washington D.C. and to be published in the Symposium Proceedings by Goddard Spaceflight Center.

IX. Recommendations concerning practical changes in operations, additional investigative effort, correlation of effort and/or results as to maximum utilization of the ERTS system.

None

X. List by date of any changes in standing order forms:

None

XI. Number of ERTS Image Descriptor Forms (Attachment B) as required by Article VII of the contract:

Attached

XII. List (by date) of any Data Request Forms (for retrospective data) submitted to NASA-GSFC/NDPF during the reporting period:

Attached

XIII. Discussion of adequacy of funds to complete task:

Funding is adequate.

XIV. Description of any significant changes in operating personnel during the reporting period or anticipated during the next reporting period.

None

References

1. Vincent, Robert K , "An ERTS Multispectral Scanner Experiment for Mapping Iron Compounds": Proceedings of the Eighth International Symposium on Remote Sensing of Environment, Ann Arbor, Michigan, Oct. 2-6, 1972, pp. 1239-1243.
2. Scherz, James P., "Monitoring Water Pollution by Remote Sensing": Journal of the Surveying and Mapping Division, ASCE, vol. 97, no. SU2, Proc. Paper 8550, Nov. 1971, pp. 307-320.
3. Yarger, H.L., et.al., "ERTS-1 Study of Reservoirs in Kansas": Proceedings of the Eighth International Symposium on Remote Sensing of Environment, Ann Arbor, Michigan, Oct. 2-6, 1972, pp. 1477-1490.
4. Yarger, Harold L., et.al., "Water Turbidity Detection Using ERTS-1 Imagery": Symposium on Significant Results Obtained from the Earth Resources Technology Satellite-1, Goddard Space Flight Center, March 5-9, 1973, pp. 651-658.

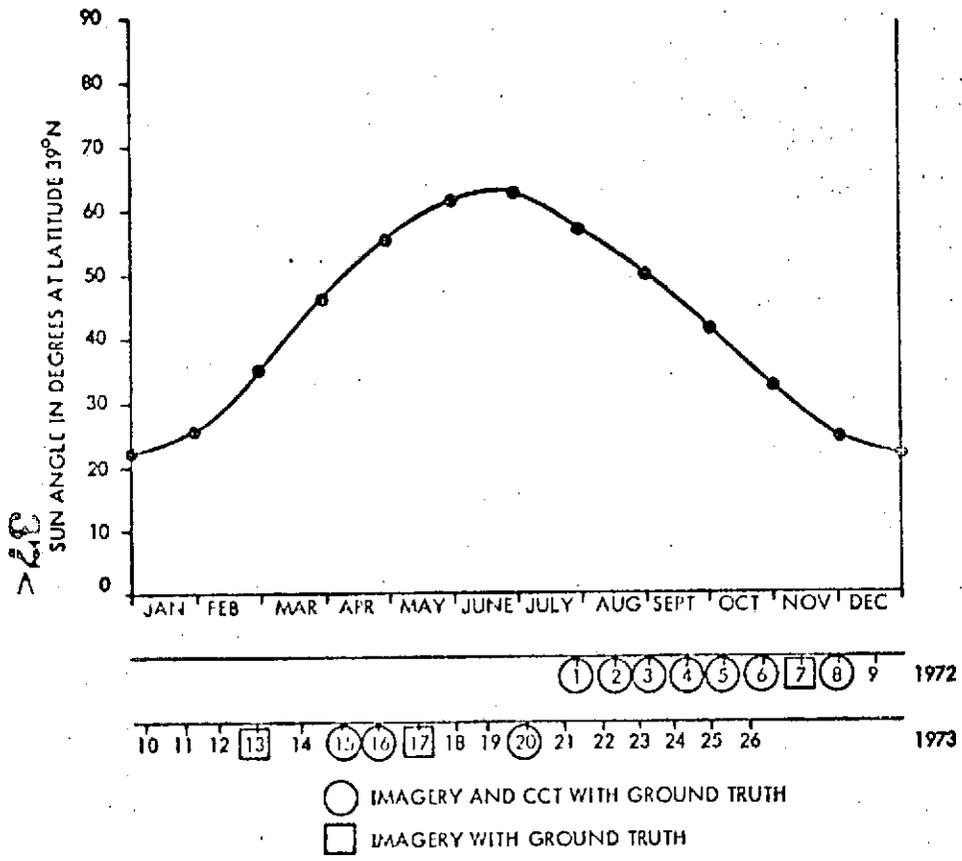


FIGURE 1. DATA ACQUISITION vs SUN ANGLE.

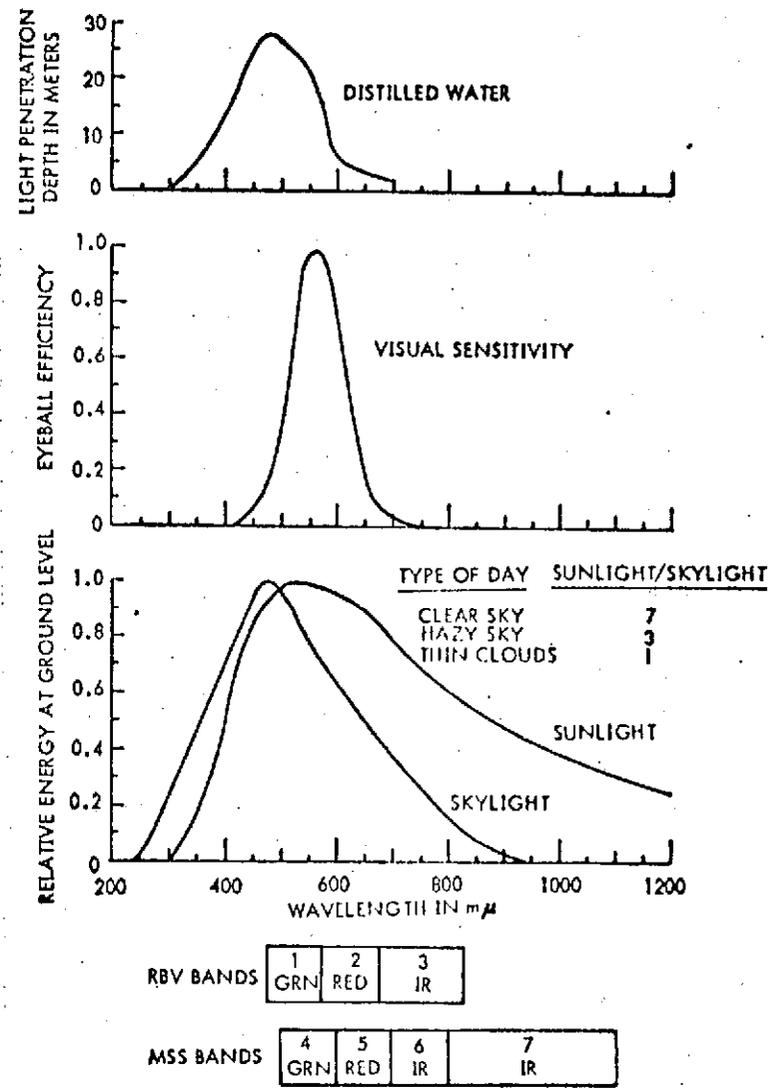


FIGURE 2. RADIANCE vs WAVELENGTH.

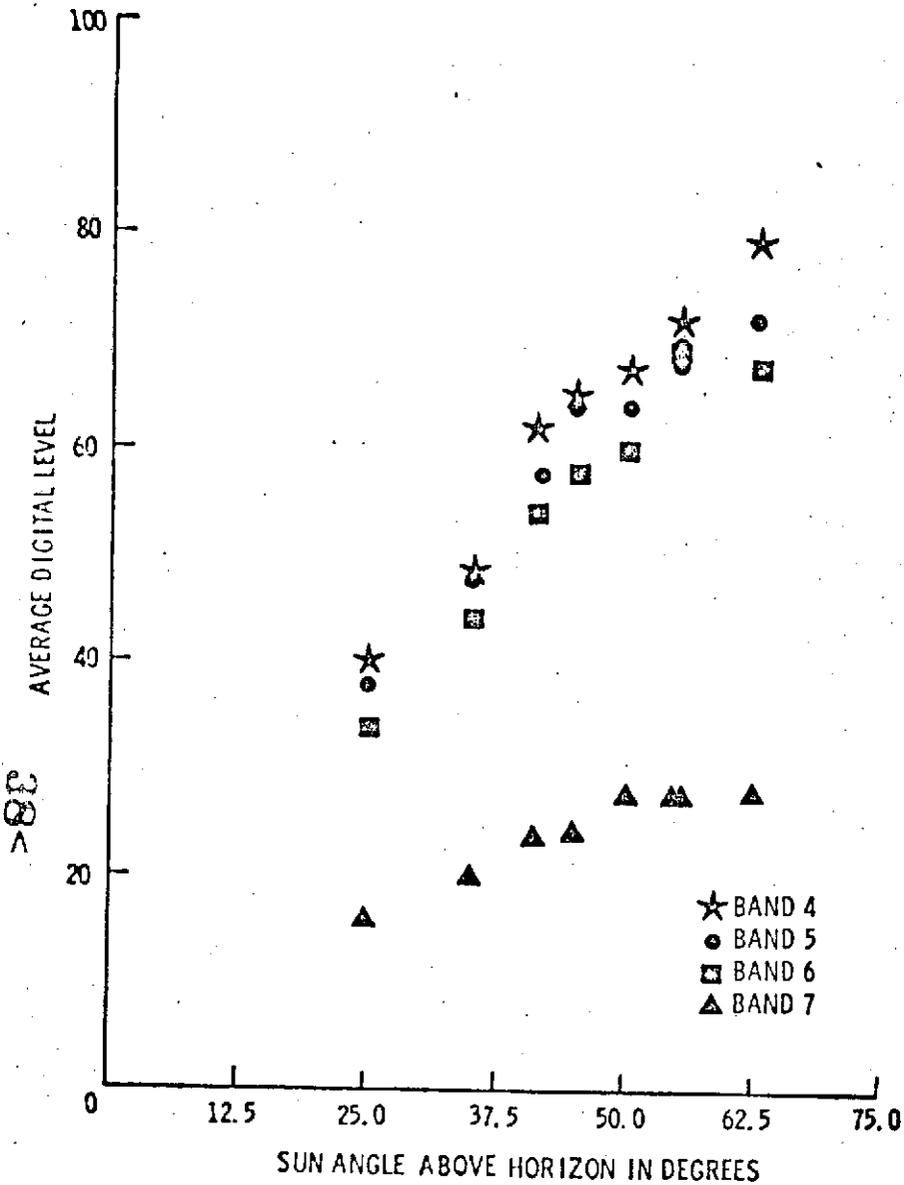


FIGURE 3. MSS DIGITAL LEVELS FROM CCT VS. SUN ANGLE FOR TUTTLE CREEK CONCRETE DAM.

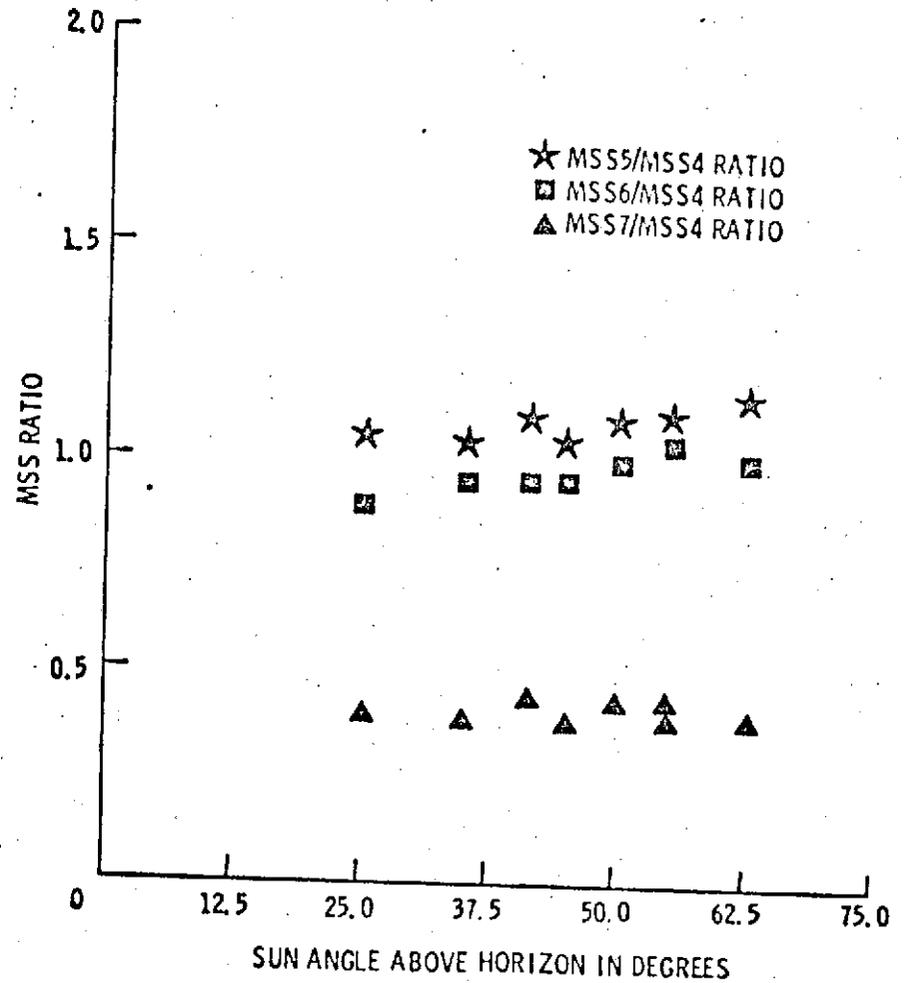


FIGURE 4. MSS BAND RATIOS FROM CCT VS. SUN ANGLE FOR TUTTLE CREEK CONCRETE DAM.

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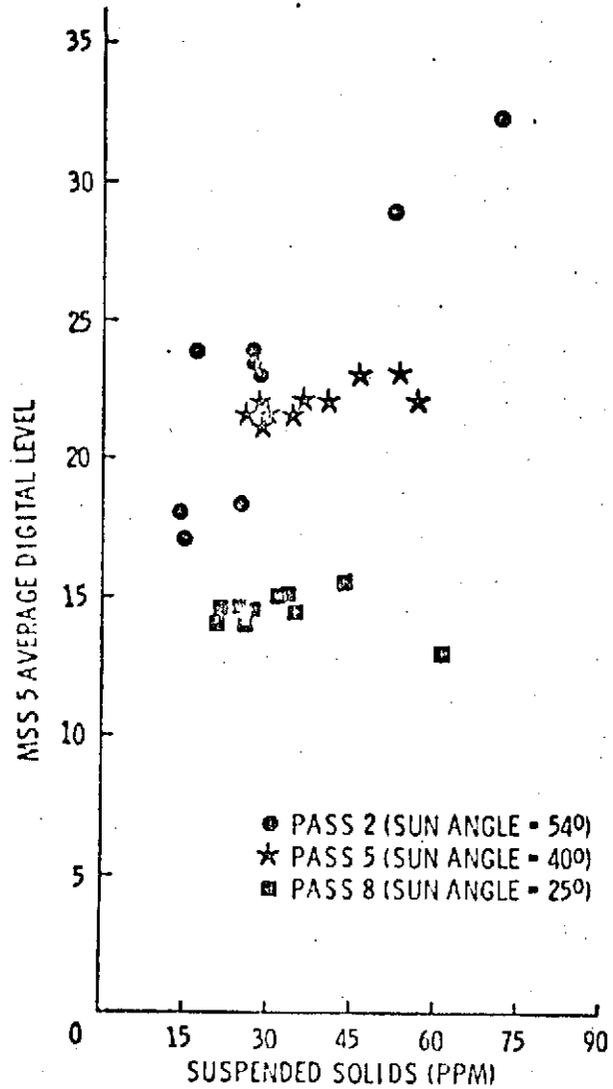


FIGURE 5. MSS5 DIGITAL LEVELS FROM CCT VS. SUSPENDED SOLIDS FOR 28 WATER SAMPLES FROM 3 ERTS-1 PASSES.

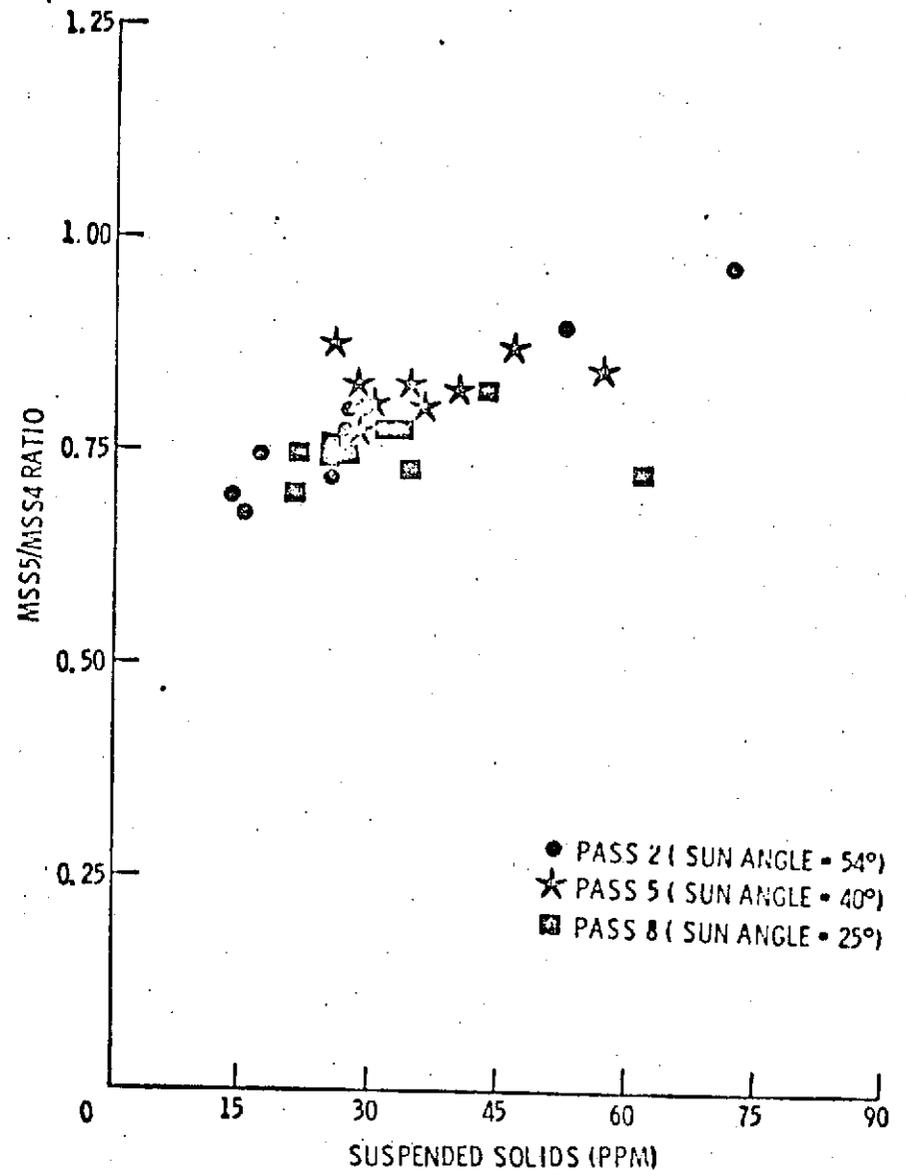


FIGURE 6. MSS5/MSS4 RATIO FROM CCT VS. SUSPENDED SOLIDS FOR 28 WATER SAMPLES FROM 3 ERTS-1 PASSES.

>07

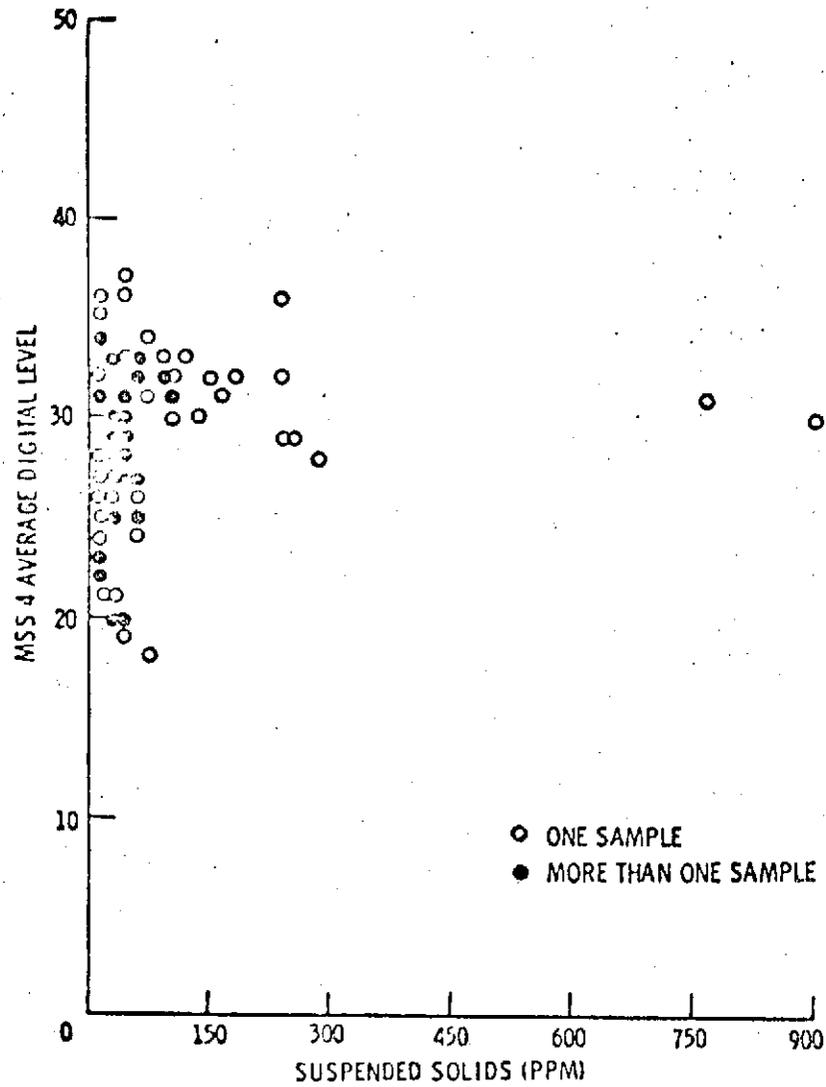


FIGURE 7. MSS 4 DIGITAL LEVEL FROM CCT VS. SUSPENDED SOLIDS FOR 108 WATER SAMPLES FROM 11 ERTS-1 PASSES.

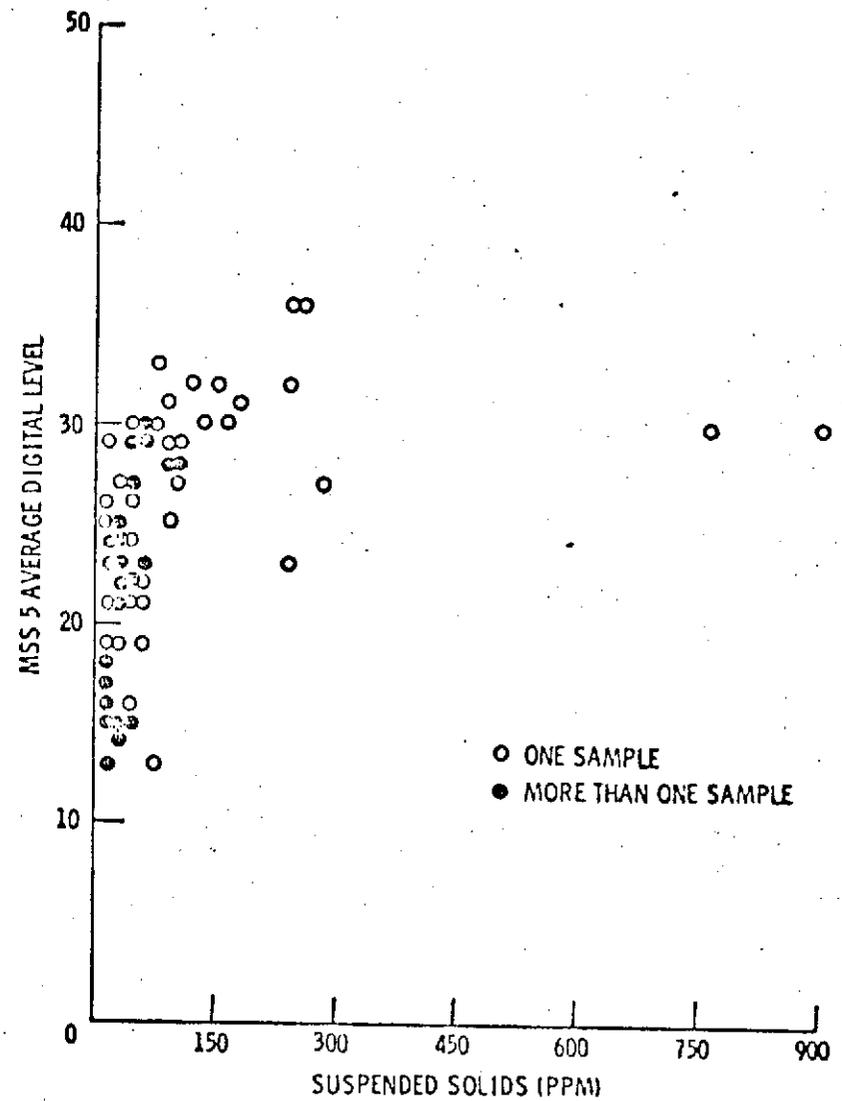


FIGURE 8. MSS 5 DIGITAL LEVEL FROM CCT VS. SUSPENDED SOLIDS FOR 108 WATER SAMPLES FROM 11 ERTS-1 PASSES.

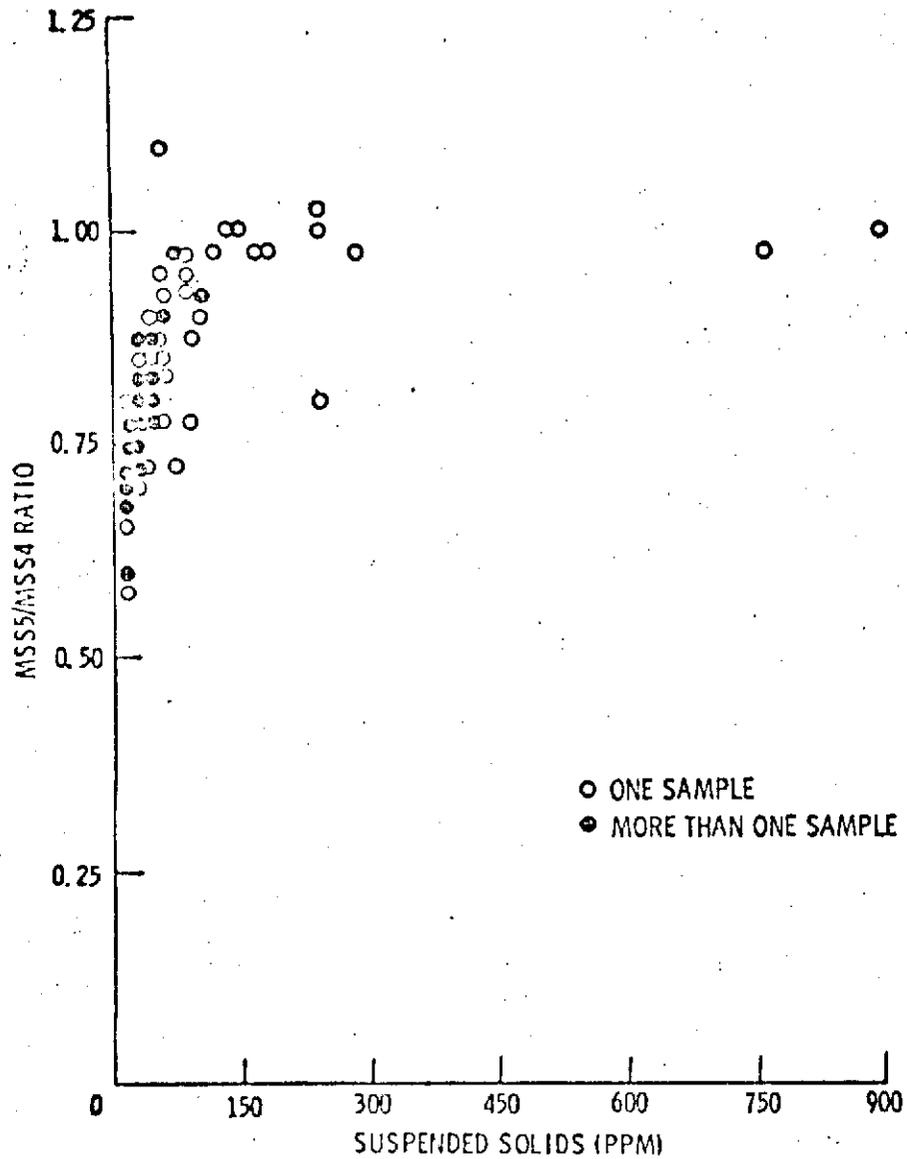


FIGURE 9. MSS5/MSS4 RATIO FROM CCT VS. SUSPENDED SOLIDS FOR 108 WATER SAMPLES FROM 11 ERTS-1 PASSES.

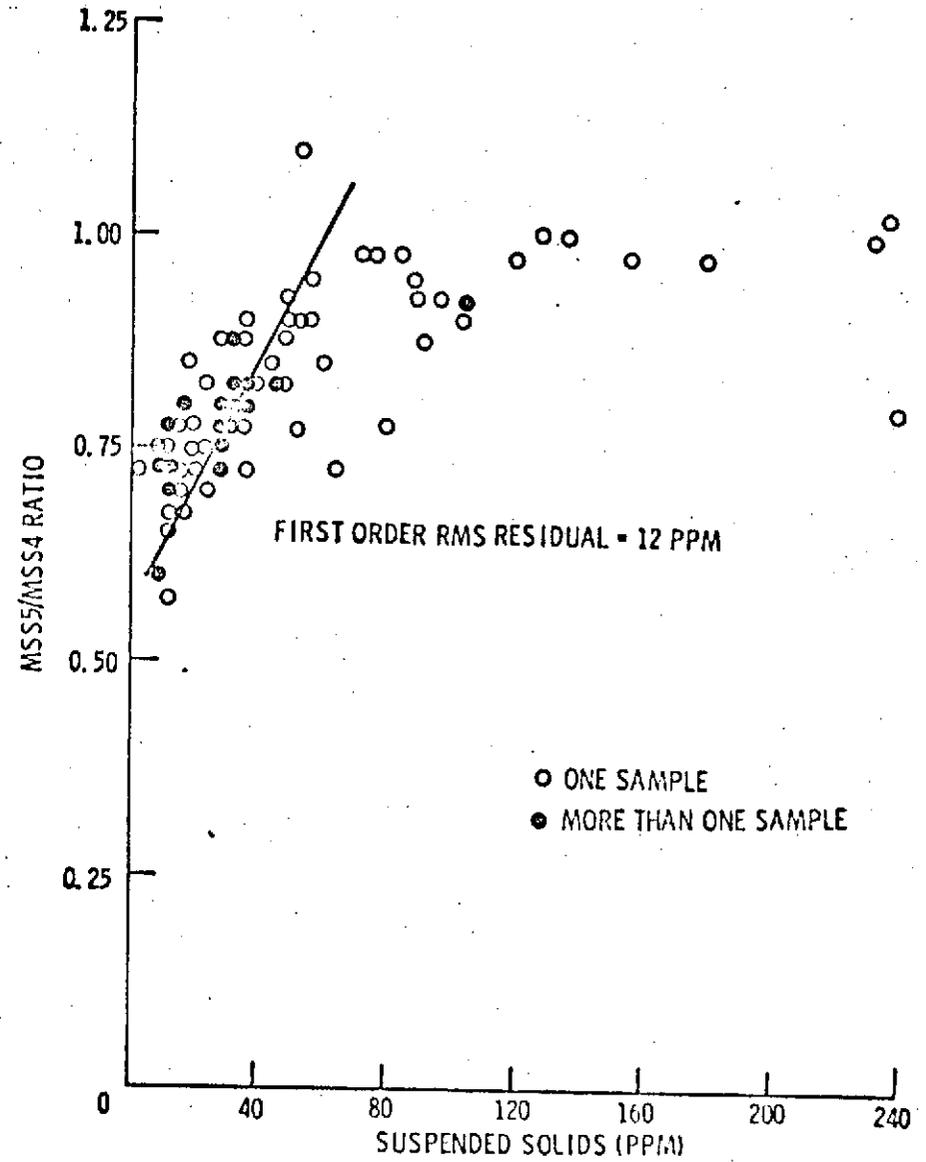


FIGURE 10. MSS5/MSS4 RATIO FROM CCT VS. SUSPENDED SOLIDS FOR 108 WATER SAMPLES FROM 11 ERTS-1 PASSES.

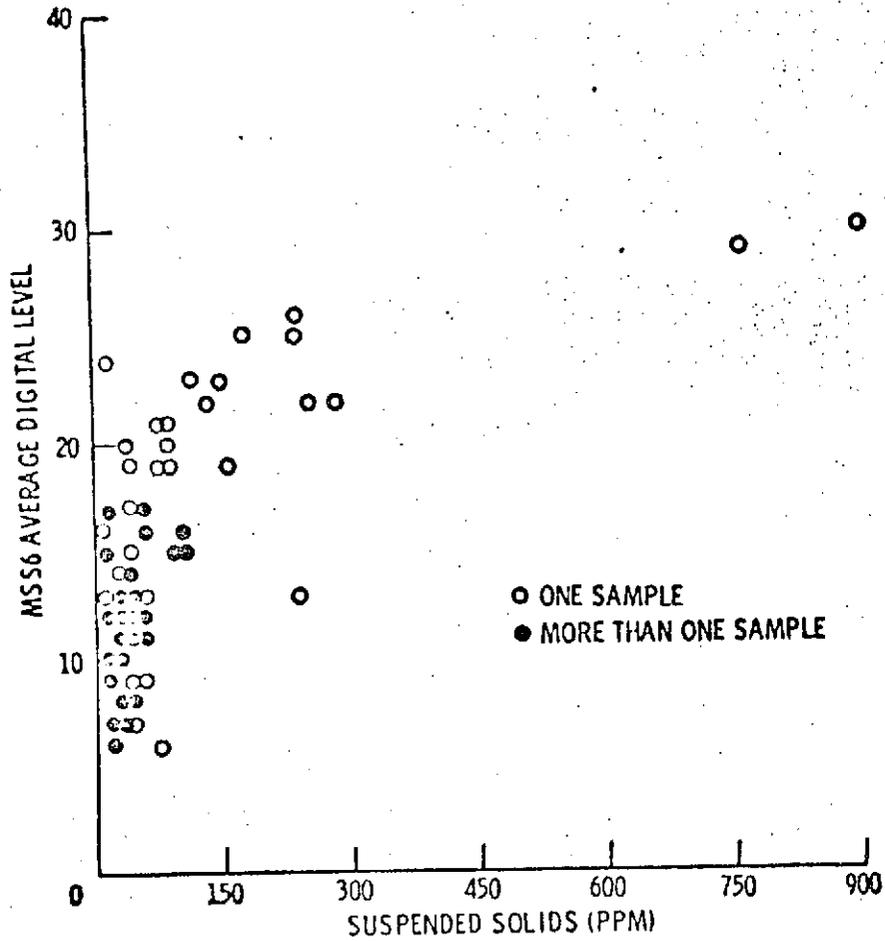


FIGURE 11. MSS6 DIGITAL LEVEL FROM CCT VS. SUSPENDED SOLIDS FOR 108 WATER SAMPLES FROM 11 ERTS-1 PASSES.

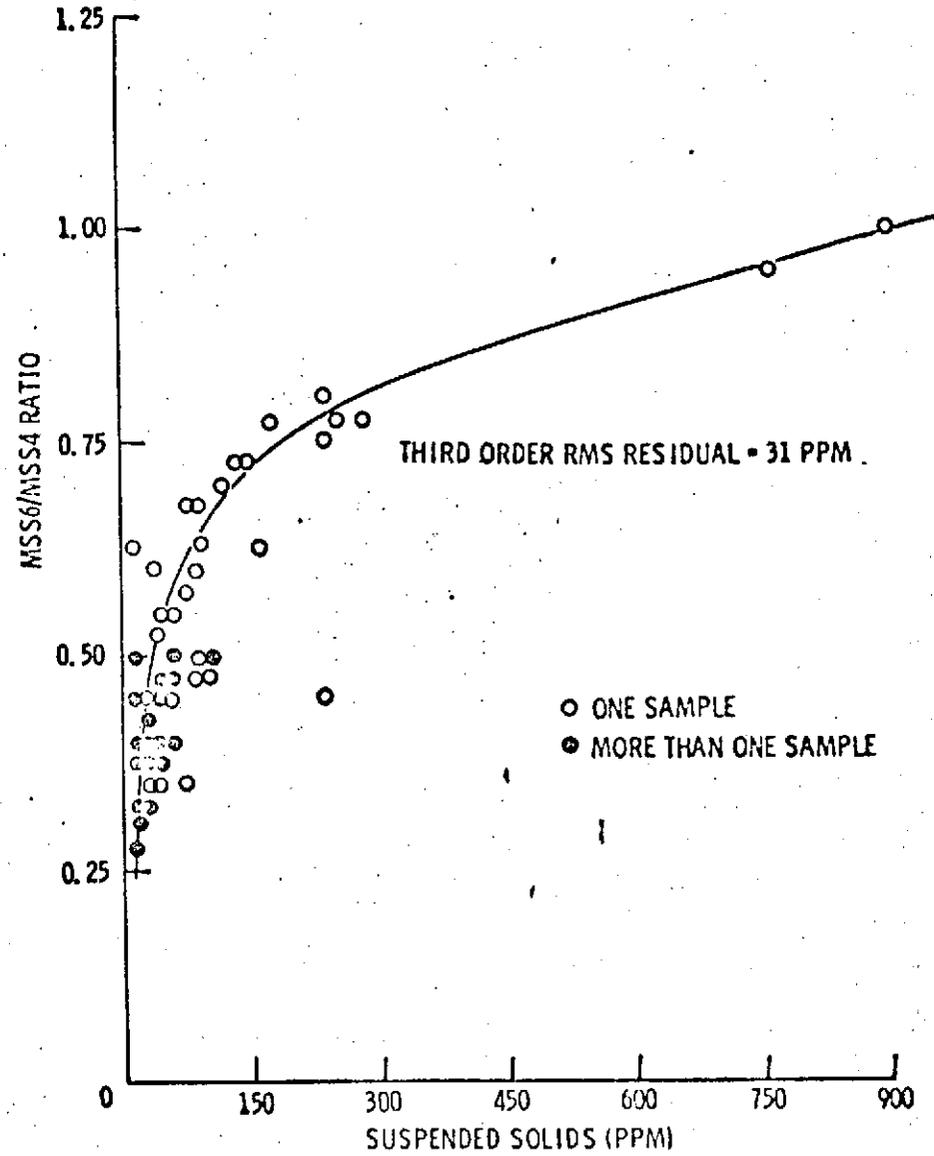


FIGURE 12. MSS6/MSS4 RATIO FROM CCT VS. SUSPENDED SOLIDS FOR 107 WATER SAMPLES FROM 11 ERTS-1 PASSES.

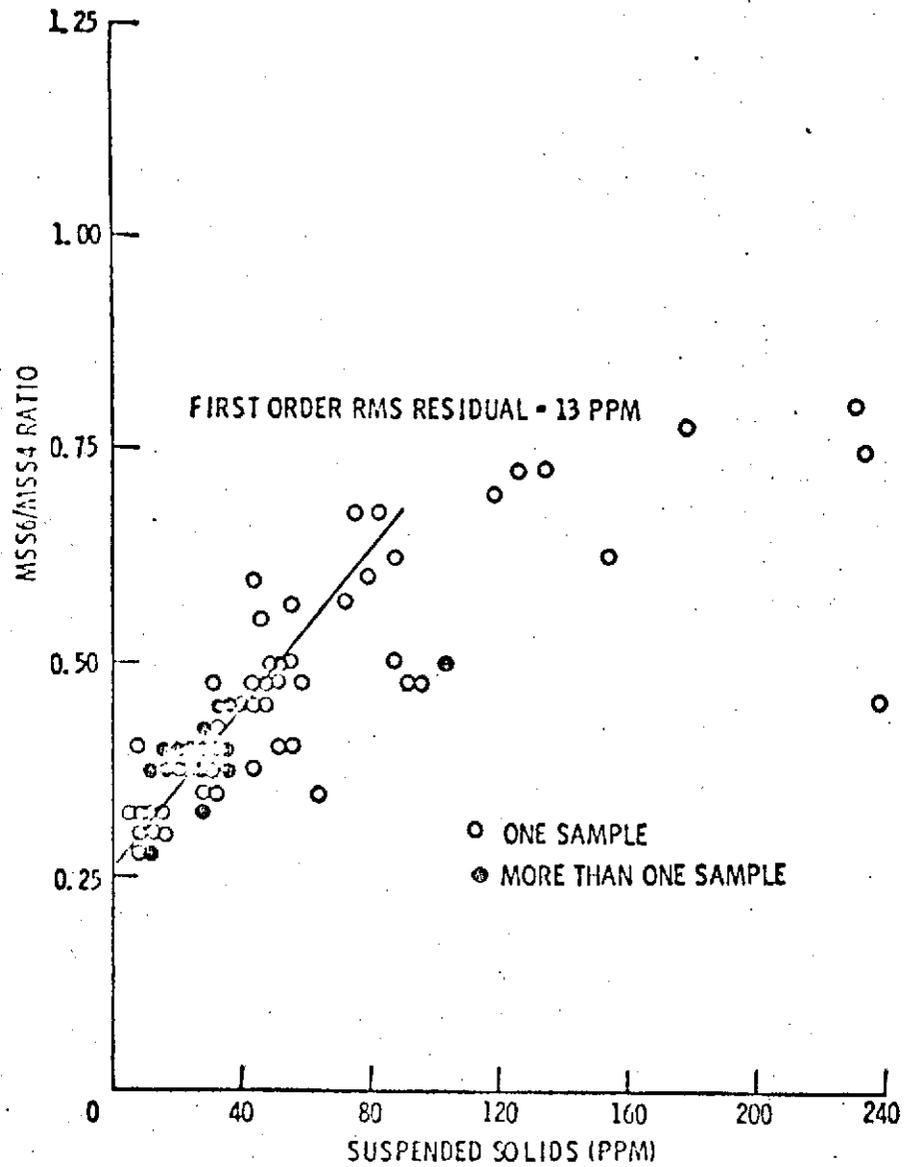


FIGURE 13. MSS6/MSS4 RATIO FROM CCT VS. SUSPENDED SOLIDS FOR 97 WATER SAMPLES FROM 10 ERTS-1 PASSES.

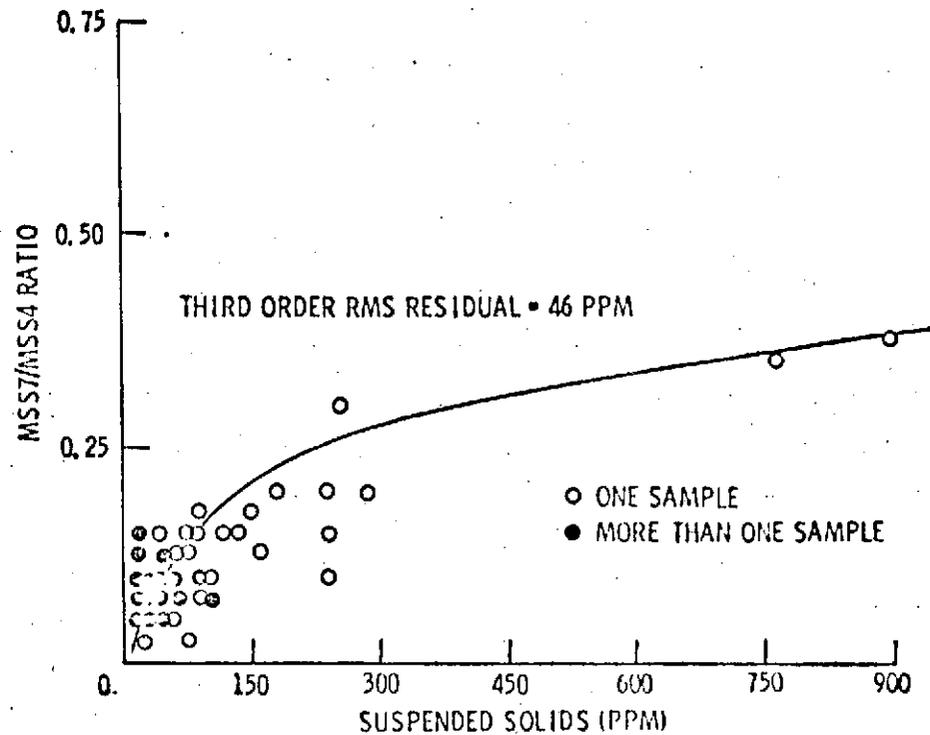


FIGURE 14. MSS7/MSS4 RATIO FROM CCT VS. SUSPENDED SOLIDS FOR 108 WATER SAMPLES FROM 11 ERTS-1 PASSES.

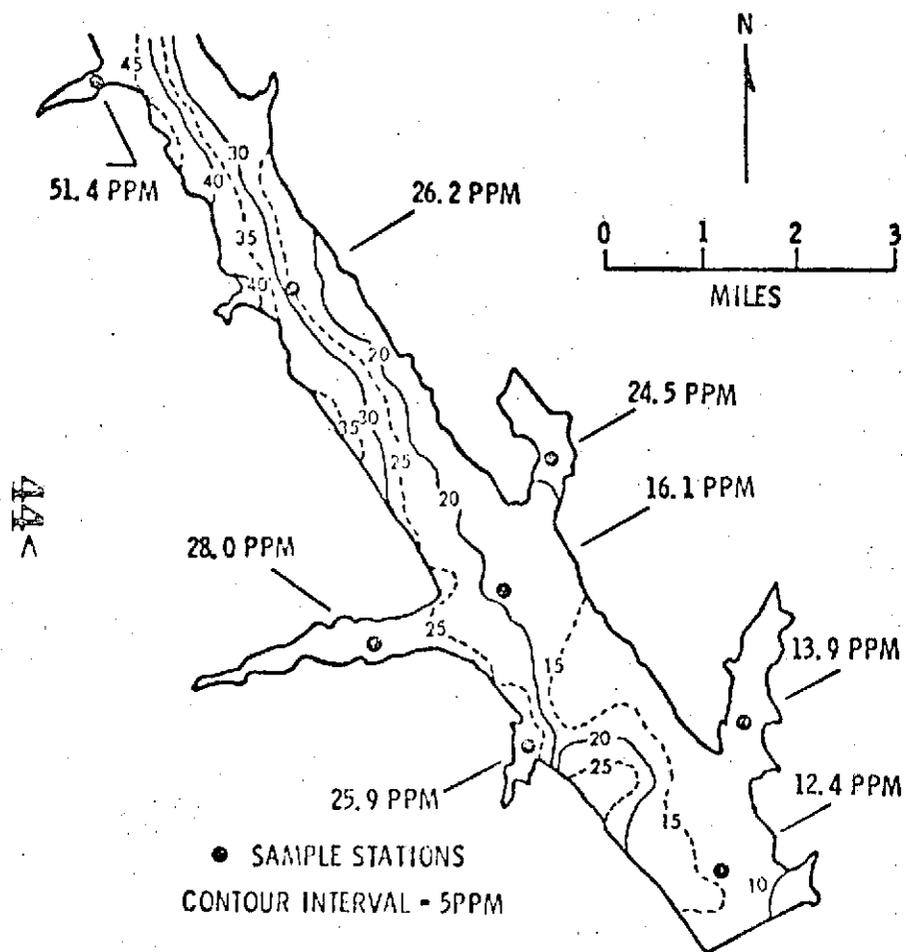


FIGURE 15. SUSPENDED SOLIDS CONTOUR MAP OF TUTTLE CREEK RESERVOIR (AUGUST 14, 1972 ERTS-1 ID NO. 1022-16391-5) DERIVED FROM CCTS (MSS 5) FOR 4 ERTS-1 PASSES.

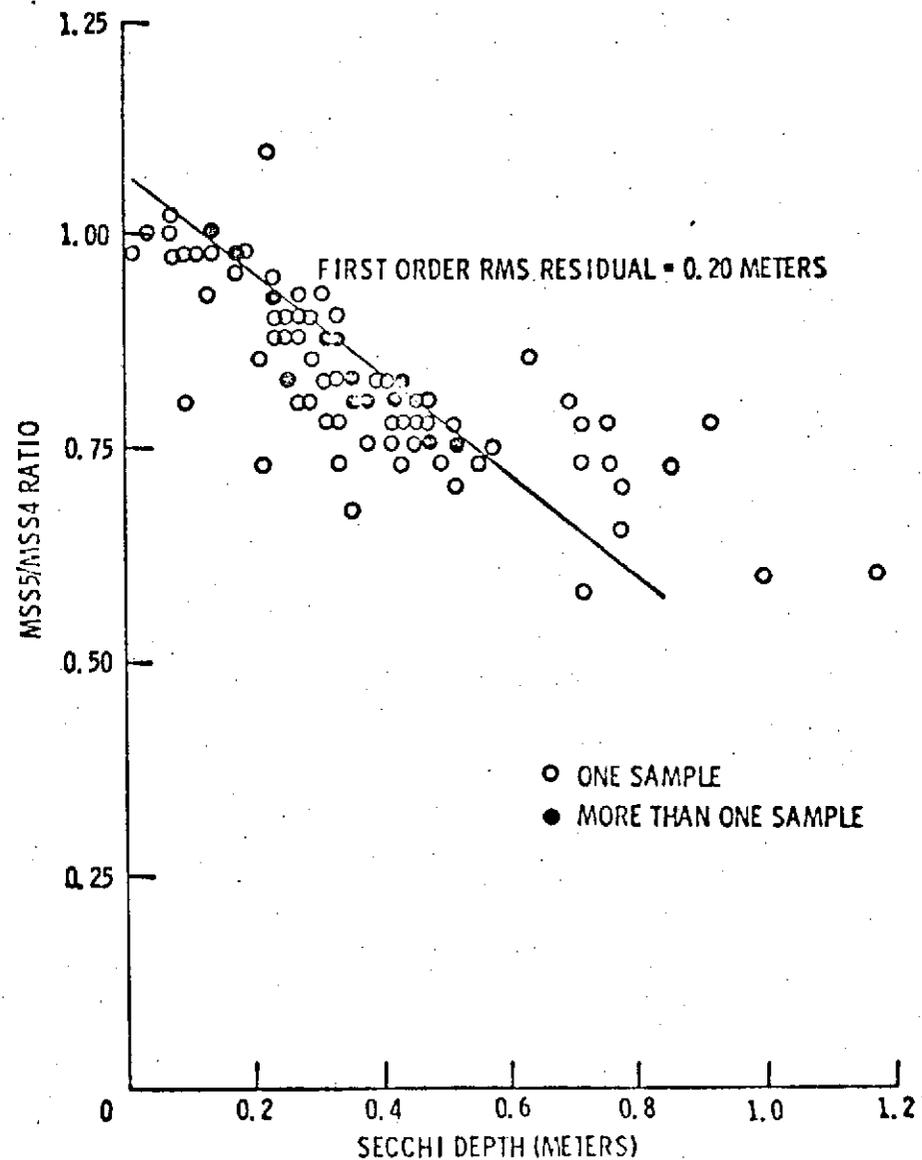


FIGURE 16. MSS5/MSS4 RATIO FROM CCT VS. SECCHI DEPTH FOR 97 SAMPLE STATIONS FROM 10 ERTS-1 PASSES.

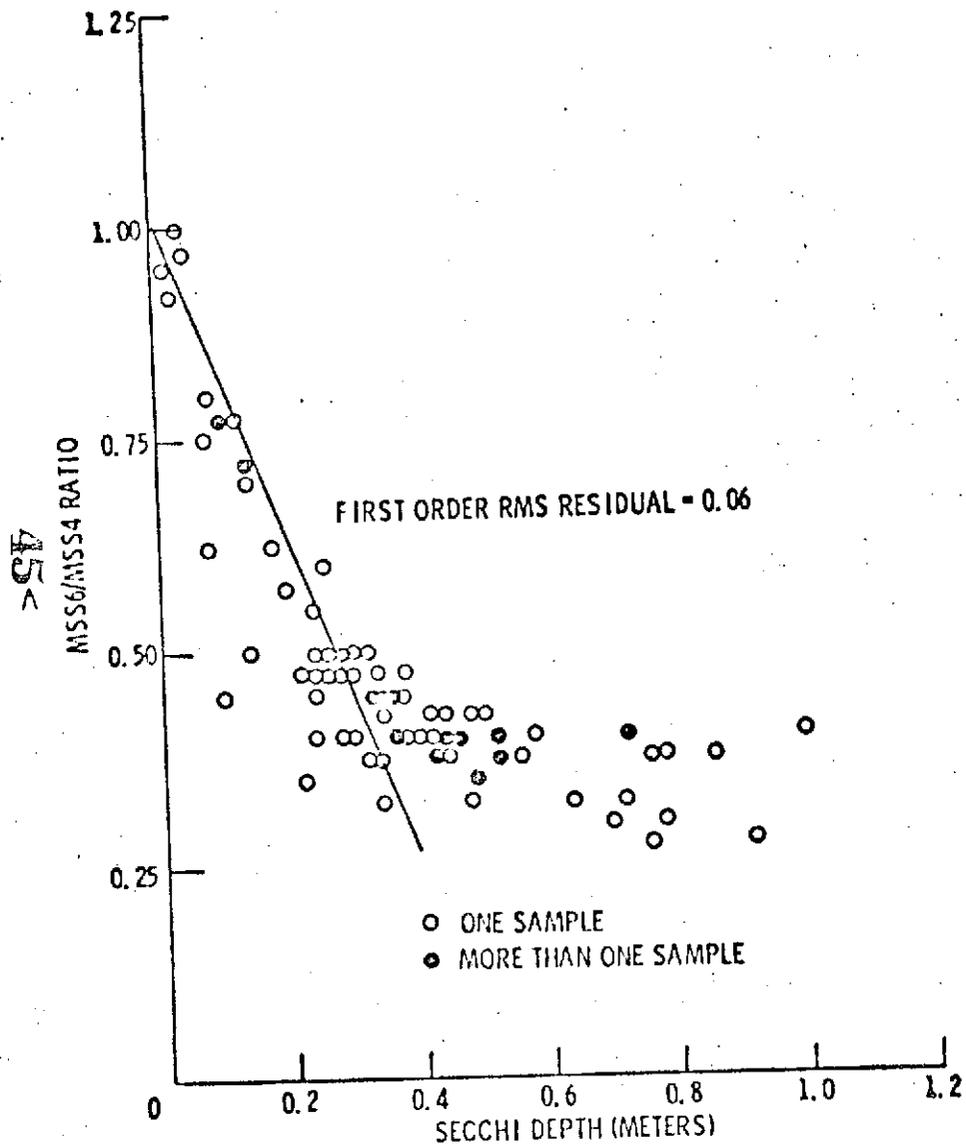


FIGURE 17. MSS6/MSS4 RATIO FROM CCT VS. SECCHI DEPTH FOR 96 SAMPLE STATIONS FROM 10 ERTS-1 PASSES.

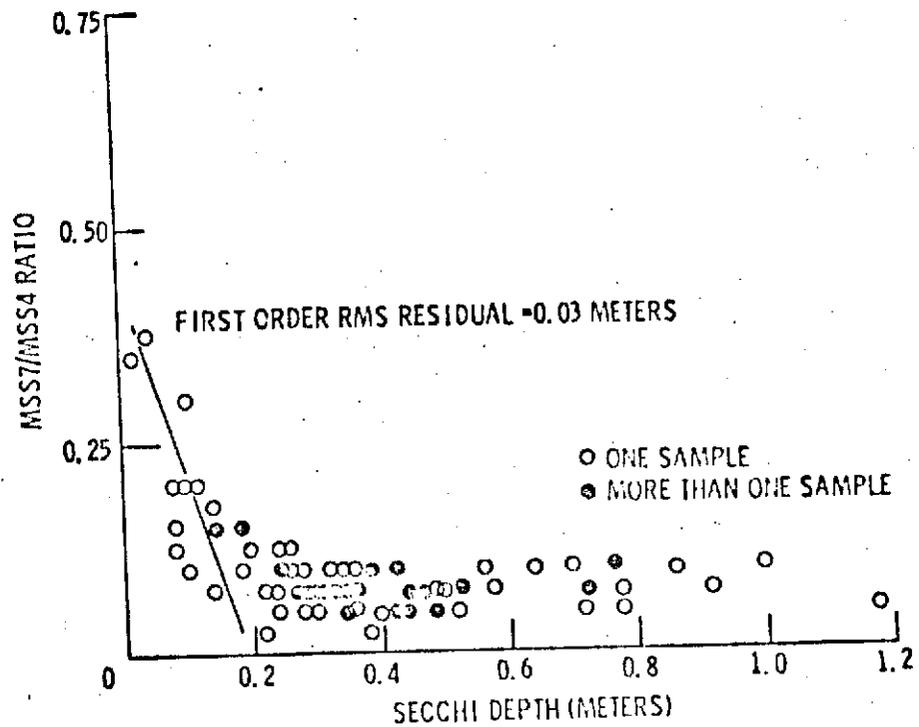


FIGURE 18. MSS7/MSS4 RATIO FROM CCT VS. SECCHI DEPTH FOR 97 SAMPLE STATIONS FROM 10 ERTS-1 PASSES.

ERTS IMAGE DESCRIPTOR FORM

(See Instructions on Back)

DATE NOV. 30 1973

PRINCIPAL INVESTIGATOR H L. YARGER

GSFC STO 45

ORGANIZATION UNIV. OF KANSAS CENTER FOR RESEARCH INC.

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PRODUCT ID (INCLUDE BAND AND PRODUCT)	FREQUENTLY USED DESCRIPTORS*			DESCRIPTORS
	STREAM	LAKE	FLOODPLAIN	
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1349-16572-4-5-7	✓		✓	
1362-16274 M				CLOUDS
1362-16281 M	✓			
1362-16283 M	✓			
1349-16563 - M	✓	✓	✓	
1347-16450 - M	✓	✓		
1347-16453 - M	✓	✓	✓	
1347-16455 - M	✓			
1367-16564 4.57	✓			
1367 16571 4.5,7	✓			

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1366 - 16503 - 5.67	✓			
1366 16510 - M	✓			
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UNIV. OF KANSAS

LAWRENCE, KANSAS 66045

ADDHHMMS OBSERVATION IDENTIFIER	C CENTER POINT COORDINATES LAT. LONG.	B SENSOR BAND	P PRODUCT TYPE	F PRODUCT FORMAT	T TICK MARKS	NN NUMBER OF COPIES	A AREA
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92-16341	38° 57'N 95° 43'W	M	D	7		1	U
92-16392	38° 48'N 97° 11'W	M	D	7		1	U
92-16332	38° 52'N 95° 43'W	M	D	7		1	U
92-16300	38° 53'N 97° 09'W	M	D	7		1	U

KANSAS ENVIRONMENTAL AND RESOURCE STUDY:
A GREAT PLAINS MODEL

Ground Pattern Analysis in the Great Plains

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December 1973
Type I Progress Report for the Period October and November 1973
Report No. 2266-7

Prepared for:

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GODDARD SPACEFLIGHT CENTER
GREENBELT, MARYLAND 20771

Contract No. NAS 5-21822, Task 6

BIMONTHLY ERTS-A USER INVESTIGATION REPORT

Type I Progress Report
for the period ending: November 30, 1973

NASA Contract NAS 5-21822

Title of Investigation: Ground Pattern Analysis in the Great Plains

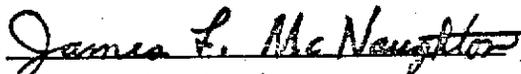
ERTS-A Proposal Number: 60-8

Task Number: 6

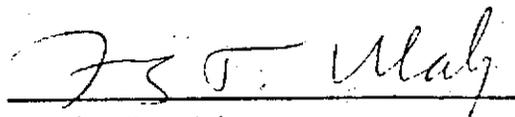
Co-Investigators: John C. Davis, Fawwaz T. Ulaby

NASA-GSFC PI ID Number: UN 657

Report Prepared by:


James L. McNaughton
Project Engineer

Report Approved by:


Fawwaz T. Ulaby
Co-Principal Investigator

I. Research Objectives:

The two program objectives of this study may be defined as:

- A. Use of multispectral imagery to map the areal geology of selected sites in Kansas, and to identify anomalous patterns;
- B. Search for large-scale ground patterns by spatial frequency analysis.

II. Problems:

None

III. Work performed during this report period:

This phase of the investigation is concerned with the quantitative analysis of the spatial frequency data obtained from sample areas in Kansas, the study of image feature enhancement techniques, and the comparison of specific results from this investigation with results from other investigations. The sample areas chosen and the information obtained from them using the optical processor (described in the appendix) was described in the ERTS-A Type II Report No. 2266-4 for July 1973.

Work concluded or in progress at the present time with respect to the data obtained in the first phase of this investigation includes the following:

- A. Determination of ground pattern classification parameters from orientation plots (intensity vs. angle curves described in the appendix).
- B. Modification of the spatial frequency plots (intensity vs. spatial frequency curves described in the appendix) to enhance the ability of the plots to display significant ground pattern information.
- C. Determination of ground pattern classification parameters from modified spatial frequency plots in (B).
- D. Investigation of the ability of the parameters in (A) and (C) to provide reliable physiographic classification of regions in Kansas in conjunction with the manual determination of distinctive ground pattern parameters.

The modified spatial frequency plots (B), were determined by obtaining an average curve for the plots and then by taking each curve, in turn, and dividing each point in the curve by the corresponding point in the average curve.

IV Planned work next report period:

During the next report period, we will be working on the following items:

- A. Comparison of ERTS-A study results with results obtained from other studies
- B. Quantitative data analysis
 1. Obtain parameters from III (A) and III (C) above and determine "best" sets to be used in classification schemes. (The results derived from III (D) will be used here to determine the most significant parameters with respect to the manual interpretation of the geologic ground patterns)
 2. Determine the physiographic classification schemes or algorithms to be employed (A number of schemes will be determined based on the parameter sets found in (1) above.)
 3. Investigate the accuracy of the classification schemes. (The results of the classification schemes will be examined to determine the identification accuracy and misclassification probability. The results will also be examined to determine how the classification schemes may be improved.)
 4. Determine the appropriateness of these classification schemes in future geologic pattern studies.

V. Reliability efforts:

None

VI. Significant results:

None

VII Cost benefits of significant results:

N. A.

VIII. Published papers, articles, reports:

None

IX Recommendations regarding maximum utilization of ERTS system:

None

X. Changes in standing order forms:

None

XI. ERTS image descriptor forms (Attachment B):

Attached

XII. Data request forms submitted:

None

XIII. Funding:

Funding is adequate.

XIV: Change in personnel:

None

APPENDIX

Optical Processing System Description

In this section we will present a description of the optical processing system used for spatial frequency analysis of the ERTS images. The optical processor has three main elements: a laser, optics, and a Recognition Systems Inc., Diffraction Pattern Sampling Unit (DPSU). The system configuration is shown in Figure 1. An ERTS-A 70 mm positive transparency is used as the input for this system. The optical processing system can be regarded as a two step system. First, an area of the ERTS transparency (sample area) is illuminated by the incident laser beam. This beam is focused by the lens (dashed lines, Figure 1) so that the point source produced by the spatial filter is imaged at a distance $z + f$ in front of the lens. The resulting light intensity distribution at this point is the optical Fourier transform or amplitude frequency spectrum of the portion of the ERTS image illuminated by the beam. Second, the intensity distribution (frequency spectrum) of the ERTS image is sampled by the DPSU.

The DPSU consists of a 64 element photodiode array (shown in Figure 2) used to detect the light intensity incident upon each element, and electronics which amplify and digitize the output from each diode in the array. The diode array is composed of 32 wedge-shaped photodiodes and 32 annular ring photodiodes. The intensity distribution across each photodiode is recorded. The data from the optical processor are then used in a computer program and are calibrated, printed and plotted.

The spatial frequency in the transform plane is related to other system parameters by:

$$s = r/d\lambda$$

where s = spatial frequency in transform plane

r = distance in transform plane measured from optical axis

d = distance from image transparency to detector

λ = wavelength of laser radiation = 6328 Angstroms

The spatial frequency obtained from this calculation is converted to ground spatial frequency using image to ground scale. The resulting curves which are plotted by the computer program are then $|c(f)|^2$ or intensity vs. frequency and $|c(\theta)|^2$ or intensity vs. angle. These are plotted in terms of ground spatial frequency in cycles per mile and direction in compass degrees from north.

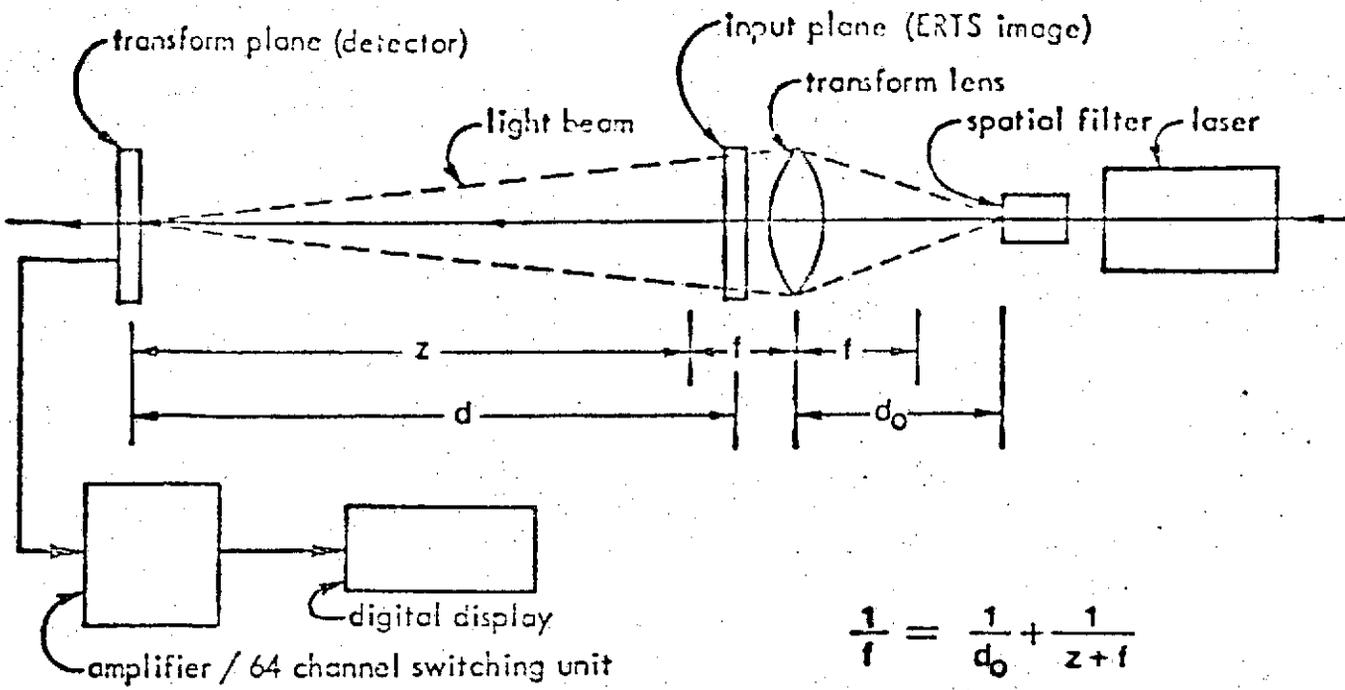


Figure 1. System configuration

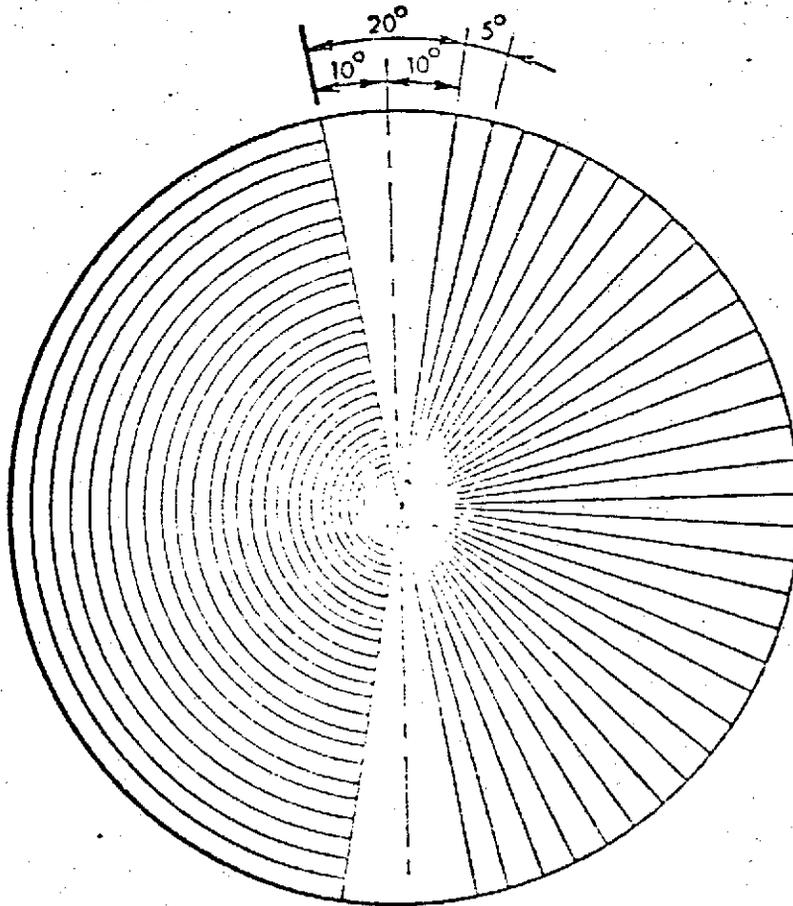


Figure 2. Detector geometry

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ORGANIZATION University of Kansas Center for Research, Inc.

PRODUCT ID (INCLUDE BAND AND PRODUCT)	FREQUENTLY USED DESCRIPTORS*			DESCRIPTORS
	Stream	Lake	FloodPlain	
1308 - 16291 - 4,5				Clouds
1310 - 16404 - 4	x		x	
1311 - 16453 - 4,5	x			
1311 - 16455 - 4,5	x			
1311 - 16462 - 4,5	x			
1312 - 16511 - 4,5	x	x		
1312 - 16514 - 4,5	x			
1312 - 16520 - 4	x		x	
1313 - 16575 - 4,5				Clouds
1314 - 17024 - 4,5	x			
1314 - 17030 - 4,5	x			
1326 - 16283 - 4,5	x		x	
1327 - 16335 - 4,5	x		x	
1327 - 16341 - 4,5	x	x	x	
1327 - 16344 - 4,5	x			
1331 - 16564 - 4,5	x			
1331 - 16571 - 4,5	x			
1331 - 16573 - 4,5	x		x	
1332 - 17023 - 4,5	x			
1332 - 17025 - 5	x			
1344 - 16284 - 4,5	x			
1345 - 16334 - 4,5	x		x	
1345 - 16340 - 4,5	x	x	x	
1345 - 16343 - 4,5	x			

*FOR DESCRIPTORS WHICH WILL OCCUR FREQUENTLY, WRITE THE DESCRIPTOR TERMS IN THESE COLUMN HEADING SPACES NOW AND USE A CHECK (✓) MARK IN THE APPROPRIATE PRODUCT ID LINES. (FOR OTHER DESCRIPTORS, WRITE THE TERM UNDER THE DESCRIPTORS COLUMN).

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PRODUCT ID (INCLUDE BAND AND PRODUCT)	FREQUENTLY USED DESCRIPTORS*			DESCRIPTORS
	Stream	Lake	FloodPlain	
1346 - 16392 - 4,5	x			
1346 - 16395 - 4,5	x	x	x	
1346 - 16401 - 4,5	x		x	
1347 - 16450 - 4,5	x			
1347 - 16453 - 4,5	x	x		
1347 - 16455 - 4,5	x	x		
1348 - 16505 - 4,5	x	x		
1348 - 16511 - 4,5	x	x		
1348 - 16514 - 4,5	x		x	
1349 - 16563 - 4,5	x			
1349 - 16570 - 4,5	x			
1349 - 16572 - 4,5	x			
1350 - 17021 - 4,5	x			
1350 - 17024 - 4,5	x			
1385 - 16560 - 4,5	x	x		
1385 - 16563 - 4,5	x			
1385 - 16565 - 4,5	x		x	
1398 - 16271 - 4,5	x		x	
1398 - 16273 - 4,5	x	x	x	
1398 - 16280 - 4,5	x	x		
1399 - 16325 - 4,5	x		x	
1399 - 16332 - 4,5	x	x	x	
1399 - 16334 - 4,5	x	x	x	

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PRODUCT ID (INCLUDE BAND AND PRODUCT)	FREQUENTLY USED DESCRIPTORS*			DESCRIPTORS
	Stream	Lake	FloodPlain	
1400 - 16384 - 4,5	x	x		
1400 - 16390 - 4,5	x	x	x	
1400 - 16393 - 4,5	x	x	x	
1401 - 16442 - 4,5	x	x		
1401 - 16444 - 4,5	x	x		
1401 - 16451 - 4,5	x		x	
1404 - 17013 - 4,5	x			
1404 - 17015 - 4,5	x			

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PRODUCT ID (INCLUDE BAND AND PRODUCT)	FREQUENTLY USED DESCRIPTORS*			DESCRIPTORS
	Stream	Lake	FloodPlain	
1384 - 16502 - 4,5	x	x		
1384 - 16505 - 4,5	x	x		
1384 - 16511 - 4,5	x		x	
1402 - 16500 - 4,5	x	x		
1402 - 16503 - 4,5	x	x		
1402 - 16505 - 4,5	x		x	
1403 - 16554 - 4,5	x			
1403 - 16561 - 4,5	x			
1403 - 16563 - 4,5	x			
1416 - 16265 - 4,5	x		x	
1416 - 16274 - 4,5	x		x	
1417 - 16331 - 4,5	x	x	x	
1418 - 16381 - 4,5	x	x		
1418 - 16384 - 4,5	x	x	x	
1419 - 16442 - 4,5	x			
1419 - 16445 - 4,5	x			
1421 - 16552 - 4,5	x			
1421 - 16555 - 4,5	x			
1436 - 16375 - 4,5	x	x		
1438 - 16491 - 4,5	x	x		
1438 - 16494 - 4,5	x	x		
1438 - 16500 - 4	x		x	
1439 - 16550 - 4,5	x			
1439 - 16552 - 4,5	x			

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PRODUCT ID (INCLUDE BAND AND PRODUCT)	FREQUENTLY USED DESCRIPTORS*			DESCRIPTORS
	Stream	Lake	FloodPlain	
1440 - 17004 - 4,5	x			
1452 - 16255 - 4,5	x		x	
1452 - 16261 - 4,5	x	x		
1452 - 16264 - 4,5	x	x		
1454 - 16371 - 4,5	x			
1454 - 16374 - 4,5	x	x		
1454 - 163380 - 4,5	x	x	x	
1457 - 16542 - 4,5	x			
1457 - 16545 - 4,5	x	x		
1457 - 16551 - 4,5	x		x	
1458 - 17000 - 4,5	x			
1458 - 17003 - 4,5	x			
1453 - 16313 - 5	x		x	
1453 - 16320 - 5	x	x	x	
1453 - 16322 - 5	x			
1455 - 16430 - 4,5	x			
1455 - 16432 - 4,5	x	x		
1455 - 16435 - 4,5	x		x	
1456 - 16484 - 4,5	x	x		
1456 - 16490 - 4,5	x	x		
1456 - 16493 - 4,5	x		x	

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